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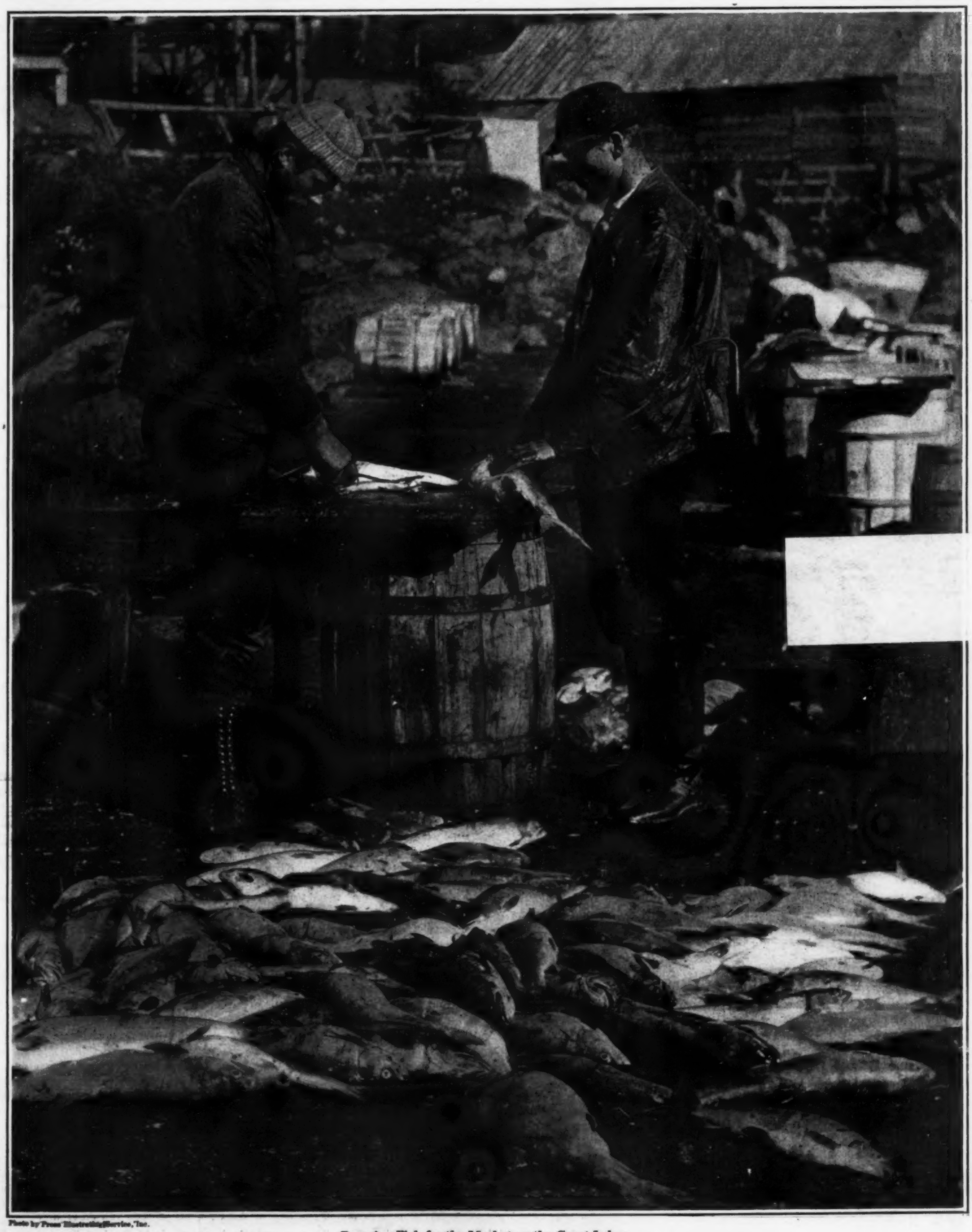


Photo by Press Illustrating Service, Inc.

Dressing Fish for the Market on the Great Lakes

LET'S EAT FISH [See page 8]

The Cost of Coal*

A Summary of the Various Elements Which Determine It

By Geo. Otis Smith and C. E. Lesher (United States Geological Survey)

THE price of coal is a matter of vital concern to the average citizen. No less important, however, is the question what our coal actually costs to produce and the interest in this subject is typical of the popular interest in the large productive enterprises of the country. As citizens we recognize the consumer's dependence upon the producer, and are taking advanced ground as to their relative rights. In few industries does this dependence seem more vital or the consumer's equity appear larger than in that of producing and selling coal. The per capita annual expenditure for the useful metals is roughly equivalent to that for coal, but few citizens purchase pig iron or bar copper, whereas of the urban population only the dwellers in apartments, boarding houses, and hotels are spared the necessity of buying coal. The consumption of coal in the United States for heating and cooking is between 1 and 1½ tons per capita. A careful estimate for 1915 is 1.1 tons, which happens to be identical with the figure determined for similar consumption in Great Britain in 1898. This nonindustrial consumption is greatest in cities, and in this city of Chicago, in 1912, it was nearly 2 tons. Of course every citizen indirectly pays for his share of the total consumption, which last year amounted to 4.6 tons per capita.

In discussing costs, however, we do not overlook the too evident fact that at times price may far outstrip cost. The price of coal depends upon the balance between necessity for fuel on the one hand and ability to produce and to deliver on the other; the ability to produce is in turn controlled by the labor available and the ability to deliver is dependent upon car supply. Increased foreign demand for American coal, large industrial consumption, unusual weather—all may have great influence on the current price of coal, but none of these is to be considered a factor in the actual cost of production, except so far as it causes irregularity in operating expenses and promotes a decrease in efficiency of mine labor. Today high prices are being received for coal by those who are able to produce and deliver more than their outstanding contracts require. In other words, a few traders may be able and willing to capitalize the urgent necessity of the consumer and their own ability to deliver.

Four general items of cost must be considered as normally controlling the price of coal to the consumer—resource cost, mining cost, transportation cost, and marketing cost. Under usual conditions each of these items includes a margin of profit which may seem either excessive or inadequate, according to your point of [illegible]. Yet an unbiased consideration of these cost items [illegible]solutely essential as a preliminary to the decision [illegible]he public whether we are buying coal at a fair [illegible], and if not, why not. As long as it is the popular [illegible] that the price of coal is made up of one part each [illegible]ining costs and freight costs to two parts each of [illegible]tor's profits and railroad dividends, with the cost of a certain amount of needless waste on the side, the demand for investigation will continue, and in so far as there is any element of truth in this view, legislative action is justified, even though the prescribed reform may approach the extreme of public ownership and operation of mines and railroads.

As the initial item of cost, the amount charged against the marketed product as the value of the coal in the ground, which for brevity may be termed the resource cost, is perhaps the item most often overlooked by the coal consumer, and for this reason that phase of the subject will be fully considered after the other items are treated. These other items need less discussion in this paper for several reasons: the item of marketing cost is one that can be brought directly under observation by the consumer if he will but study the matter intelligently; the transportation cost can be learned by simple inquiry, and its control lies within the province of the Interstate Commerce Commission, and the details of mining cost can best be set forth by the mine operators themselves, for they have now adopted the policy of free discussion of these matters, which they once regarded as sacred from public view. The purpose of this paper, then, is simply to give a [illegible]ummary statement of all these elements in the cost [illegible] coal, and some special discussion of the resource [illegible]

The item of cost first to be considered represents that part of the value given to the ton of coal by the mine operator and the mine worker. This may be termed mining cost, but it must include the operator's selling costs and other overhead expenses as well as the mining costs proper, which include the larger expenditures for wages, supplies, and power. This cost plus the resource cost—the royalty or depletion charge—and the profit or loss on the sale make up the value at the mine mouth. The mining cost varies not only between mines of different companies in separated fields, but even between adjacent mines of the same company in the same field. Both nature and man contribute to such variation.

It is not practicable to assign a very exact figure to the mining cost—the census of 1909 indicated an average of $1 a ton for bituminous coal and $1.86 for anthracite, but these figures are believed by some operators to be too low. It is possible, however, to show in a general way the distribution of this item; the cost of mining is divided between labor, 70 to 75 per cent; materials, 16 to 20 per cent; general expense at mine and office and insurance, 2 to 4 per cent; taxes, less than 1 per cent to 3 per cent for bituminous coal, and 3 to 7 per cent for anthracite; selling expenses, nothing to 5 per cent, and recently to these items has been added the direct and indirect cost of workmen's compensation, which may reach 5 per cent for bituminous coal. The charges for labor, material, and general office expenses are easily understood, as is also a charge for depreciation of plant and machinery; but taxes and selling expenses are important items that may be overlooked by the casual observer. Some figures recently published show that the taxes levied in West Virginia last year on coal lands and coal-mine improvements—that is, on the industry as a whole—were equivalent to nearly 3 cents net per net ton of coal produced, which is doubtless fully as much as the profit made by the operators in that State.

The cost of selling coal is nothing for the companies that use their own product, including the Steel Corporation and a large number of others, and is little or nothing for the producers who sell nearly all their coal to such large consumers as the railroads. Companies that produce coal for domestic use and the general run of steam trade must figure on a selling cost as high as 10 cents or more per ton, the cost depending on the extent of their business. The average selling cost for bituminous coal is probably 5 to 10 cents a ton, and for anthracite the usual charge of sales agencies is reported as 10 cents a ton for steam sizes and 15 cents for the prepared sizes.

The producers of coal and the transportation companies are concerned not so much with the actual rates charged for carrying coal as with the adjustment of rates between different coal fields and between different markets. In the many years in which our coal industry has been developing, rate structures have been built up that give to this and that producing district differentials over other districts—"handicaps," as it were—that may be based on comparative lengths of haul or on the ability of the coals to compete by reason of difference in quality or in cost of mining, or perhaps may be merely the survival of past practice, for which no reason now exists. The consumer of coal, however, is interested in the actual rather than the relative freight rate.

To help toward a realization of the magnitude of this transportation item, it may be pointed out, first, that all but 14 per cent of the output of the country's coal mines, aggregating 532 million tons, is moved to market by rail or water, and second, that nearly half of the bituminous coal (47 per cent in 1915) and more than two-thirds of the anthracite (71 per cent in 1915) is shipped outside of the States in which it is produced.

Add to this statement of the extent to which coal enters interstate commerce a glance at the distribution of centers of maximum production and maximum consumption—the New York-Baltimore industrial zone, which has a total per capita consumption of nearly 10 tons and lies 100 to 400 miles from the tributary coal fields; New England, consuming about 7 tons to the unit of population and lying 400 to 800 miles from its coal supply; or the populous industrial district of which Chicago is the commercial center, consuming 8 to 9 tons per capita of coal, in part hauled more than 400 miles from the fields of West Virginia and eastern Kentucky and in part 200 miles or less from the Illinois mines. With these facts in mind we must realize that the transportation cost is necessarily a large part of the country's fuel bill.

In the interstate traffic, both rail and water, bituminous coal probably pays an average freight of nearly $2 per ton. In other words, the transportation costs more than the product and, as some parts of the country are just now learning, is sometimes more difficult to obtain. The value of coal, like the value of so many other commodities, is a place value.

The average freight charge on anthracite is higher than that on bituminous coal, first because the rates are higher, and second because, according to the reports of the Interstate Commerce Commission, *all* movement considered, the coal is carried a greater distance.

The cost of handling the coal, exclusive of freight, from the time it leaves the producer until it is in the consumer's fuel bin, may be termed the marketing cost. It can readily be seen that a large part of the coal produced is not subject to this cost, for most large users of steam coal, such as the railroads and the coke manufacturers, place contracts directly with the producing companies or their selling agencies and buy in the open market only when their needs exceed the deliveries under their contracts. Much of the coal, however, both anthracite and bituminous, passes through the hands of a wholesale dealer or jobber before it is received by the retail dealer, who puts it in our cellars or in the bins of a power plant. Coal that gets a long way from the mine may pass through many hands before it reaches the consumer, and it not only pays commissions all along the line, but is subject to shrinkage and deterioration, both of which enter into the final selling price to the consumer. Brokers are usually satisfied to make a gross profit of perhaps 10 cents a ton, but as several brokers may make a "turnover" on the same car before it is unloaded this element of cost may be several times that amount.

About half of the anthracite and around 15 per cent of the bituminous coal is retailed in less than carload lots, and the greatest number of individuals are directly concerned in the marketing of this portion, regarding the profits on which there is the widest divergence of opinion. The margin in the retail business between cost on cars and price delivered is between $1.25 and $2 a ton, and is not more than enough to give on the average a fair profit. The shrinkage and, in part, the deterioration are together seldom less than 1 per cent of the weight and may exceed 4 per cent, and the retail dealer also must provide in his selling price for uncollectible accounts.

Advertising is a large expense—in part carried by the retailer directly, but all borne by the industry. The largest single item in the cost of retailing is of course that representing the labor of handling and the local cartage, which together make up about half the marketing cost.

There now remains to be considered the first major item, or the resource cost, which is what the operator has to pay for the coal in the ground—the idle resource, which he starts on its career of usefulness. This cost is expressed as a royalty or a depletion charge.

One of the latest leases by a large coal-land owner provides for the payment of 27 per cent of the selling price of the coal at the breaker. This percentage is therefore not only a royalty figured on the mineral resource, but also a commission based on the miner's wage. To bring this right home to you and to me, it may be said that the practical result is that if the anthracite we burn in our range this winter happens to come from that particular property, we will pay fully $1 a ton into the treasury of the city trust that owes its existence to the far-seeing business sense of a hard-headed citizen of Philadelphia. Whether such a royalty is excessive or not, the fact remains that this is the tribute paid to private ownership.

The present average rate of royalty on anthracite is probably between 32 and 35 cents a ton on all sizes, which is from 12 to 14 per cent of the selling value at the mine. The minimum rate (about 10 per cent) is found in some old leases, and the maximum (20 to 27 per cent) in leases made in the last five years. R. V. Norris states that in the late sixties, when the annual

*A paper read before the American Mining Congress, Chicago, November 14, 1916.

output of anthracite was around 15,000,000 tons, royalties were 8 to 10 cents a ton on prepared sizes, but that no charge was made on the smaller sizes. In the seventies the rate rose to 25 cents on prepared, one-half that on pea, and one-fourth on smaller sizes. By the middle eighties, when the output was a third what it is now, the rate was about double that of the seventies—that is, 40 to 50 cents on the larger sizes and 5 to 10 cents on the smaller sizes. The tendency is still upward by reason of increases in the rates for intermediate sizes, and the operation of royalty rates, based on a percentage of the selling value, an increasing quantity. Figured on the output from the Girard lands, which is nearly 3 per cent of the total production, the gross return to the estate from its coal lands is over 50 cents a ton.

Nor is the increase in value of anthracite lands any less striking. At the beginning of the last century, as stated by Mr. Norris, the great bulk of these lands were patented by the State of Pennsylvania for $2 to $4 an acre; in the middle of the century the price of the best land rose to $50, and in 1875 even to $500. Now $3,000 an acre has been paid for virgin coal land, and little is on the market at that. In considering these increases in land values, the effect of interest and taxes must not be overlooked.

The bituminous coal industry is a modern institution compared with the mining of anthracite, and much of the bituminous coal land was acquired by the operating companies during the last 20 years for little if anything more than its surface value. Today there are large areas of bituminous coal-bearing lands that because they are undeveloped and without railroads, can be purchasel at a low price, but little or no anthracite land is on the market, and little has changed hands for years. The present average resource cost of bituminous coal is not much over 5 cents a ton, or about 4 per cent of the average selling value at the mine. In the Pocahontas region and the Pittsburgh district the royalties are much higher, but these, like others that might be cited, are exceptions—one due to coal of special quality, and the other to location—factors which, incidentally, are exactly those that have assisted in making the resource cost of anthracite what it is.

Should you be interested in summing up all these various costs and striking a balance between labor's share and capital's return, you would find that the mine worker, the trainman, and the wagon driver together receive fully half of the price of the anthracite delivered at your house, and the same three classes of labor receive not less than half the price paid by the average consumer for the cheaper soft coal. In a similar manner the average return on the capital invested in land, mining plant, railroads, and coal yard may be roughly calculated, with the result that landlord, bondholder and stockholder of coal company and railroad together receive about $1.15 from the ton of anthracite and only 50 to 75 cents from the ton of bituminous coal, and of either of these amounts the mine operator's share is only a small fraction.

It is not the purpose of this analysis of costs to offer any cure-all for the high price of coal, yet some comment on the facts presented may possess value. At least certain lines of approach can be pointed out as not very promising. For example, anyone who is at all cognizant of the trend in price of labor and material can see little hope of relief in lower costs for these items. Furthermore, observation of the advances made in mining methods in the last decade or two affords slight warrant for belief in any charge of wasteful operation. As consumers of coal we might do well to imitate the economy now enforced by the producers in their engineering practice. In the Northern Anthracite field machine mining is extracting coal from 22 and 24-inch beds, and throughout the anthracite region the average recovery of coal in mining is 65 per cent, as against 40 per cent only 20 years ago. Nor are the bituminous operators any less progressive in their conservation of the coal they mine.

Yet it must be remembered that conservation of a natural resource, though it will undoubtedly be of direct economic benefit in the future, is not essentially a cheapening process; in fact, these increased recoveries of coal have in large part become possible only because of a higher market price. And, following further this line of thought, we may say that the increased safety in the coal mines that has come through the combined efforts of the coal companies, the State inspectors, and the Federal Bureau of Mines necessarily involves some increase in cost of operation, but the few cents per ton thus added to the cost is a small price to pay for the satisfaction of having the stain of blood removed from the coal we buy.

In the item of transportation perhaps the most promising means of relief is that of reducing the length of haul. Though many a consumer's preference for coal from a distant field over that from a field nearer home is based on special requirements, the deciding element in the preference of other consumers is simply the price, and this in turn may be largely due to a differential freight scale, which is thus not in the public interest if we admit the premise that it is wasteful to burn coal in hauling coal into coal districts or past such districts, except in so far as quality requirements absolutely demand the long-haul coal.

Reduction in marketing costs is a reform so close to the consumer that he should be able to find for himself whatever relief is possible. Professor Mead, of the University of Pennsylvania, is authority for the statement that the delivery of coal is costing the dealers 50 cents a ton more than is necessary.

There only remains, therefore, the first item of all—the value of the coal in the ground, or rather the return which the land-owner is asking for this natural resource. The fortunate holder of coal land, whether a very human individual or a soulless corporation, or a large trust estate administered for benevolence only, is likely to endeavor to get all that the traffic will bear. Especially in the possession of a limited resource like anthracite, the tendency has been and will continue to be to increase royalties as the years pass, and the only penalty imposed by the State for high royalties seems to be high taxes, which too often, indeed, serve to justify the high resource cost put upon coal in the ground. Finally, in considering royalty rates or depletion charge we must not overlook the interest that accumulates throughout the period between the purchase of the coal land and the removal of the last ton of coal.

In placing a value upon the Choctaw lands some years ago, the Geological Survey figured the aggregate royalties at current rates as 160 million dollars, but if that amount of royalty were to be collected through the six or seven centuries required for mining the two thousand million tons under this land, the present value of the land would be only 6½ million dollars if purchased by the Federal Government, or only 4 million if purchased by the State of Oklahoma, and even less if the project were financed by a corporation that would need to issue 6 per cent bonds. Such is an illustration from actual experience in coal-land valuation—the 4 or 6 million dollars invested in these Oklahoma coal lands now would require a final return of 160 million dollars in royalties to balance the account.

More recently Mr. Cushing, the editor of *Black Diamond*, has figured the cost of a monopolistic control of the available coal resources east of the Rocky Mountains on the basis of the United States Geological Survey estimate of two million million tons. At a valuation of coal in the ground of only 1 cent a ton, which, as he stated, is less than has been paid for large holdings, this deal would require a capitalization of 20 billion dollars, and the fixed charges on the bonds of this United States Coal Corporation would require an interest charge alone of $2 a ton against a production of 600 million tons a year. Mr. Cushing characterizes such a financial undertaking in mild terms as hopelessly impossible, and yet his figures, which do not include taxes, are most enlightening as affording some measure of the cost of possessing an undeveloped resource. Incidentally, these startling figures furnish a strong argument for the present policy of the National Government in retaining ownership of the public coal lands, at least up to the time when the market conditions justify the opening of a mine, and then either leasing or selling a tract only large enough for that operation. The consumer of the next century simply can not afford to have private capitalists invest today in coal land for their great-grandchildren to lease.

The burden that seems evitable under unregulated private ownership of a natural resource like coal is that because the lands containing these national reserves of heat and power are taxed and because the individual or corporation properly charges up interest at current rates on his large holding, the consumer must pay a resource cost which takes into account the long period of undevelopment. Even the high rates of royalty on the lands of the Girard estate may be found less excessive than they seem if a century's taxes and interest charges are figured. Yet the fact remains that the royalty for anthracite represents a much larger proportion of the cost of the mined coal than any bituminous royalties. Moreover, we believe the highest royalty prevailing in the anthracite region has far more influence in fixing the selling price than the lower rates of the older leases.

Any study of costs in the coal industry finds its point in the question, not who but what fixes the price of coal. The cost of mining coal, like the cost of living, is increasing. Exact mining costs, however, can not be determined until the operators have accomplished their reform of standardizing accounting. Too often the operator includes in his account only the two largest and most obvious items, labor and material. Thus, when the market for bituminous coal is dull, the company whose land costs little or nothing is able to set a lower limit of price than the company whose coal must stand a charge of 5 to 10 cents per ton, or even more, be that charge called royalty, depletion, or amortization. At such times the operator with the larger resource cost must sell at a real though not always recognized loss, but of course with the hope of recouping himself at times of high prices like the present, if fortunately he has any coal to sell not already contracted for.

Even with the average low resource cost of bituminous coal, the state of competition that is tied up with idle and half-worked mines results in an average total cost that is little below the average selling price. Of course in this business there are those, both large operators and small, who make a profit in lean as well as in fat years, just as there are those for whom the prosperous years are too infrequent to keep them out of the hands of receivers.

In the anthracite fields the mining costs, and especially the resource costs, are higher. But here, with an average market demand that normally exceeds or at least equals the available supply (and with the passing years this disparity must be expected to increase), there results naturally a lack of competition for the market. Even gentlemen's agreements are unnecessary as long as every operator can reasonably expect to sell his product, and the market price of anthracite at the mine must therefore tend to be fixed by the operator who has the largest mine and resource cost, rather than by his neighbor who may be doubly favored with a mine less expensive to work and a lease less exacting in terms.

Confessedly, this analysis of the cost elements that enter into the price of coal emphasizes our lack of specific facts, which can be supplied in the future only through "installation of uniform cost-keeping methods and uniform and improved accounting systems," to quote from the declaration of purposes of the Pittsburgh coal producers. With the results of such book-keeping in hand, more definite reply can be made to the public's appeal for relief from high prices. Yet even now it may be possible to suggest how that relief will eventually be obtained. Study of present conditions in the coal mining districts fails to encourage the idea of governmental operation of the seven thousand coal mines in this country. More in line with the trend of public sentiment in the last decade, however, is governmental control in the interest of the consumer by regulation of prices.

Competition seems to have failed of late years to benefit the consumer of coal. In the bituminous fields the competition whenever present has been wasteful, and in the anthracite fields there has been practical absence of healthy competition, and whether too great or too little competition, the result is the same—to increase the actual cost of bituminous coal by saddling the industry and its product with the fixed charges on idle or semi-idle mines, and to raise the price of anthracite coal by favoring the burdens of high resource costs.

In estimating the aggregate losses incurred by society by reason of the large number of mines not working at full capacity, the facts to be considered are that the capital invested in mine equipment asks a wage based on a year of 365 days of 24 hours, while labor's year averaged last year only 230 days in the anthracite mines and only 203 days in the bituminous mines, with only 5 to 8 hours to the day.

As coal is more an interstate than intrastate commodity, any regulation of prices needs to be under Federal control, and to benefit both consumer and producer such control can not stop with transportation and mining costs, but must stand ready to exercise full rights as a trustee of the people over the coal in the ground. The private owner of coal land, which derives its real value from society's needs, has no more sacred right to decide whether or not that coal shall be mined when it is needed by society or to fix an exorbitant price on this indispensable national resource than the coal operators have to combine for the purpose of exacting an excessive profit from the consumer, or the railroads to charge all that the traffic may bear. The proposal to bring land-owner under the same rule as mine operator and coal carrier may seem radical, but where is the point at which coal becomes the resource upon which industrial society depends for its very life?

Anomalies in the Animal World—Part VI.

The Origin of Vertebrate Animals We Call Birds

By Dr. R. W. Shufeldt

SINCE the complete demonstration of the law of organic evolution, there is no fact that science has been enabled to better establish, and which the ever-accruing evidence tends continually to substantiate, than the one elucidating the origin of existing birds. That they arose far back in geologic time from prehistoric ancestral reptilian stock there can now be no question. From those long extinct archaic ancestors not only descended the group of vertebrated animals we call birds, but all existing reptilian forms as well. Back there, in the youth of life upon this planet, there were no such forms as birds, and there were no such animals as we now designate as reptiles. It was at a time back in years reckoned by millions, since which every animal of that pristine stock has been extinct for untold ages; and, what is equally certain, thousands of families, tens of thousands of genera, and an inconceivable number of species, have become extinct since.

During this extinction of archaic forms and the evolvement of new ones—which in turn, over and over again, became extinct, only to make room for others—birds gradually came into being. Modern birds and modern reptiles are now completely differentiated, and the distinguishment has long been established. No existing reptile possesses feathers, and no existing bird is without them; while feathers, so complex in their structure, did not, by any means, come into existence in any brief space of time. Yet many millions of years ago there existed small, reptile-like birds, having excellent powers of flight and being covered with perfect feathers. In this connection it is but necessary to mention the *Archaeopteryx* of the Jurassic.

Doubtless there were in those times other bird-like forms, varying in size, that were clothed with feathers, or else feather-like structures, and that were not able to fly, or enjoyed the power of flight only to a slight degree. In the line of ancestry of birds, the first flying animals were certain long extinct reptiles—that is, reptiles of the archaic eras—very different creatures, indeed, from the ones now so named. In those times, too, existed other reptile-like animals endowed with the power of flight, with which birds have no kinship whatever. All these and allied facts, however, have, for some years past, been set forth both in scientific and popular works, so that intelligent readers are more or less familiar with them.

The power to navigate the air by vertebrated animals on this planet, as such animals evolved, is a very long and a most interesting story. This cannot, however, command more of our space here; there remains but one fact to be brought forward from all this voluminous history: that the comparatively few birds still existing—which are either entirely without that power or only enjoy it to some slight degree—are derived from ancestors wherein the matter of flight was probably more or less perfect. In other words, the wings of birds have come about through the *result* of flight, and in no instance have they ever been the *cause* of it. Moreover, in such birds as ostriches, the wings have degenerated, and the ancestors of such forms probably had these limbs fully developed and could fly well. It is further likely that they were not nearly as large or as bulky as existing ostriches and their kin. When this is stated, it must be borne in mind that there are those who claim that all the recently extinct, as well as the living ostrich forms, are the descendants of certain groups of palæontologic reptiles that walked bi-pedally. Many of our barnyard fowls have fully developed wings or fore limbs, yet they cannot use them for flight.

Some fowls are of big and bulky proportions, and they, through artificial selection, were derived from much lighter and smaller species, which, with no better wings, were at the same time strong flyers. We breed fowls in such a way as to preserve their wings; but the time may arrive—if our own species remain carnivorous in the ages to come, and these fowls still exist—when the wings of some of them will, in the remote future, in various degrees degenerate.

Within comparatively recent times, various flightless birds, in different parts of the world, have become extinct; likewise, in the existing world's avifauna, there are other flightless or nearly flightless species, the majority of which are very near the same sad fate. Whenever a species becomes extinct, that extinction is for all time; in other words: no extinct animal is ever reproduced; once extinct, always extinct, and to this rule there are absolutely no exceptions. So, when man has destroyed the last bird on this planet, the class will have been exterminated forever; and before feathered forms of any kind, endowed with the power of sustained flight, could again be evolved, this planet will have become as cold as its moon without a spark of life upon its surface.

Fig. 1—An Ostrich Family

Fig. 2—Palapteryx

Of flightless extinct birds probably no species has been more extensively written about than the great toother diver, *Hesperornis*, of the Kansas Cretaceous. Many years ago (January, 1886, p. 352) a restoration of mine of this loon-like species of the American continent of several millions of years ago, appeared in the *Century Magazine* of New York City. Since that time a skeleton of that ancient pogopodine has been placed on exhibition at the United States National Museum, and my study of this skeleton has materially changed my views with respect to the external appearance of this form. Were another restoration ever published by me, it would depart, in a number of particulars, from the one which appeared in *Century*.

Hesperornis had wings that were a long ways toward complete reduction; only the arm bone (humerus) remained in each, and the bird could no more fly than can an ostrich of the present day. Indeed, its rudimentary fore limbs were utterly useless to it, while an ostrich can at least employ its own as locomotory auxilliaries when, running in high winds, it desires to turn abruptly; in other words, to double to escape its pursuers.

Ostriches and their young have been photographed a great many times in different parts of the world, the one illustrating the present article (Fig. 1) having been obtained by Mr. Glenday, at Cape Town. The cock bird stands exactly eight feet high, and is an unusually fine specimen.

All the Struthiones or ostriches, wherever they occur or may have occurred, whether existing or extinct forms, are typically representative of flightless birds. No ostrich of any kind, as an Emu, or a Cassowary, or a Rhea, or any of their near allies, have ever been birds of flight; one would never think of an ostrich flying any more than one would of a camel doing so.

Among the extinct flightless ostrich forms, we have the family *Palapterygidae*. They were New Zealand birds of great size, and known to us only through their subfossil remains. These exhibit dinornithic characters connecting them with the Moas, which latter will be referred to further on. As in the case of the Moas, however, it may be stated here that *Palapteryx*, the typical genus of the *Palapterygidae*, was contemporary with man, and so was the other genus of the group, *Emyapteryx*, both genera being represented by two species. I present in Figure 2 a *Palapteryx*, which is a reproduction of a photograph made by me of my *Century Magazine* illustration; it is after the outline drawing of Professor Hochstetter's restoration, and as an outline drawing it has been extensively reproduced in many places. These birds had the hind toes, in which they differed from the more typical ostriches.

True Moas were great, ostrich-like birds that once inhabited New Zealand and its off-lying islands, but which are now extinct. From 1838 on, a large quantity of their bones and other remains have been sent to England, and described in various scientific journals by such eminent writers as Owen, Hutton, Haast, and others. Professor Owen claimed that one of these Moas, *Megalapteryx huttoni*, was feathered to the toes. Its habitat was Middle Island, New Zealand, and its appearance is well shown in Figure 3, which is a reproduction of a photograph made by me of Plate 41 of the Hon. Walter Rothschild's sumptuous volume on "Extinct Birds" (1907). As a matter of fact, quite a number of the illustrations of the present part were obtained by me in the same manner, acknowledgments of these being given in the legends to the cuts; and when given to Rothschild, it is to be understood that the cut in question is from his "Extinct Birds," from a photograph of it by me.

Moas have their name from the aborigines of New Zealand—the Maoris, who exterminated them. Rothschild says: "The Moas at one time must have been extraordinarily numerous, both in numbers and species, and they varied in height from two and a half feet to twelve feet. Professor Parker has shown that some of the species had crests of long feathers on the head, and, as some adult skulls of the same forms show no signs of this, he infers that the males alone had this appendage." This eminent authority further states that "the Maoris arrived in the North Island some 600 years ago; that they hunted Moas, and that they exterminated them about 100 to 150 years after their arrival. In the South, or rather Central, Island, the Maoris appear to have arrived about 100 years later, and to have exterminated the Moas about 350 years ago. It is only fair to say, however, that Monsieur de Quatrefages adduces evidence in this paper which goes far to prove that Moas existed down to the end of the 18th or even the beginning of the 19th century, in those

Fig. 3—Megalapteryx Huttoni (Owen) after Rothschild

parts of the Middle Island not, or scantily, inhabited by Maoris" ("Extinct Birds," p. 186).

Moas belong to the family *Dinornithidae;* a very remarkable genus of that family has been named *Dinornis*—immense and long extinct birds, of which about seven species have been described. More or less perfect skeletons of these, and a few feathers, are in some of the museums of England. They all occurred in New Zealand, and a fine example of the genus is reproduced in Figure 4, *Dinornis ingens*, of Owen. It was about eleven feet high, and one of the birds exterminated by the Maoris. Tring Museum has an almost perfect skeleton of it. Other genera of the *Dinornithidae* are *Megalapteryx* and *Anomalopteryx*.

Ponderous, as well as flightless birds, after the ostrich order, also compose the family *Aepyornithidae*, of which there are at least three genera and a number of species; these all came from Madagascar and have long been extinct.

Emu-like birds of large size, belonging to the genus *Dromaius*, also extinct, have been recognized through their remains, which explorers have found on the islands of Tasmania—that is, King Island, Flinders and Kangaroo Islands. As an example of these, we have, in Figure 5, *Dromaius peroni*, which formerly inhabited Kangaroo Island. There is a stuffed specimen of this bird in Paris (type), and there are bones of it in other museums. The sides of its neck were featherless and blue, while the plumage was chiefly dark brown and black. Peron brought three of the birds alive to Paris, but these were the last of their race. *D. minor*, also extinct, occurred on King Island, Bass Strait.

It is more than likely that a number of other extinct forms of ostrich birds will come to light through the discovery of their remains in various quarters of the globe as time passes. In the United States there also existed, during geologic time, great struthionine forms of enormous proportions, that probably were quite as flightless as ostriches. These belonged to the genus *Diatryma* of Cope, a second species of which has recently been described by me, and which was a bird of enormous proportions, at least three or four times as big as an African ostrich.

Returning to the existing ostrich types which, as stated above, are all flightless, and have direct ancestors which are extinct and found in fossil condition, there are to be noticed the Rheas (*Rheidae*) of South America. There are three species of these, and they occur in different regions from northern Brazil to Patagonia. All of the birds are large forms, and very much resemble the ostriches of Africa—indeed, they are quite generally known as South American ostriches, while, in the matter of their anatomy, they stand higher in the scale. Rheas possess three toes instead of only two, as in the ostrich; the former likewise has the head and neck feathered; its wings are larger, and the tail much better developed. In the chase, they exhibit enormous endurance, tiring out both dogs and horses, unless they happen to be of the very best stock and in excellent form. On the pampas of Argentina

Fig. 4—Dinornis Ingens, after Rothschild

the natives hunt them on horseback with the "bolas." The young are striped, and the egg of this species is very large and of a cream color. Only one fossil species of Rhea has been described, while two other extinct forms are related to them. As in the case of most species of ostriches, it is only the male Rhea that performs the duty of incubation; and several females lay in the same nest.

There are four known species of existing ostriches, all belonging to the genus *Struthio*. One of these occurs in Soudan and southern Palestine, while the three remaining ones are found in different parts of Africa. They are the biggest of all living birds, as an old male may attain a weight of 300 pounds. It has been stated that they can, in running, make 26 miles an hour, outstripping any ordinary horse. Their legs have, in time,

Fig. 5—Dromaius Peroni, after Rothschild

become strongly adapted to this power of marvelous locomotion and speed, while, if they remain long enough in the wild state—which is to be very much doubted—they will have but a single toe remaining on each foot,—the third of the avian *pes*. The male assists the female in incubation, and through their alternate sitting, the clutch is never deserted until the fifteen

Fig. 6—Cassowary. By the author after a colored plate of S. C. Payne & Co.

eggs are hatched out. A life history of this bird would furnish ample material for a sizable volume, and it would surely be a most interesting book.

From the ostriches and rheas we pass to the cassowaries and emus, two other genera of the existing flightless birds of the ostrich group. Most of their plumage is made up of *double* feathers, and they all lay dark green, rough-shelled eggs, the young being conspicuously striped longitudinally with black and white for some time after they are hatched out. There are some fourteen species of cassowaries still found in the existing avifauna of the world, and these are distributed over the various islands of the East Indies (Ceram, Aru, New Guinea, etc.), New Zealand, and Australia. The appearance of one of these birds is given in Figure 6, which I copied photographically from a painting of the common species. They are most brilliantly colored birds, and this gay coloration is found in both sexes. In addition to this brilliant plumage there is, in some species, a richly tinted casque or helmet on the head, which gives the species a most striking appearance, and this is enhanced by the highly colored bare skin and wattles below it. In the wings there are a series of long, black, shiny spines not found in any other kind of ostrich bird, and in these they have an excellent weapon during their conflicts. The males are very pugnacious, and in their fights dangerous wounds are inflicted by the immense nail growing on the inner toe. With this weapon they can cut a man most severely, and it is by no means a safe procedure to approach a wounded cassowary. They are forest-loving birds, and the handsome species found in Australia is now being exterminated very rapidly by man for its skin, of which rugs are made. These slayers of the Australian cassowary are as greedy and as merciless as the plume hunters of Florida, or the Japanese murderers of the sea-fowl of Laysan. Fossil remains of cassowaries are rare, and but few have been found.

[TO BE CONTINUED.]

Differential Dilatometer

This apparatus, which is of the recording type, traces a curve automatically, whose ordinate represents the expansion of the metal under study, with reference to a standard piece made of a special alloy known as "baros," or nickel 90 per cent and chromium 10 per cent. The expansion is thus indicated as the difference between the tested metal and the standard bar. The present apparatus is simple in construction and quite sensitive, and because of its differential method it gives excellent indications. Using ferro-nickel containing 59.2 per cent nickel and also electrolytic iron, the instrument will indicate the contractions which accompany the magnetic effects.

A Cycle in Naval Architecture*

With the sanction of the British Admiralty, M. Rousseau, naval critic of the Paris *Temps*, has given the world an account of those new additions to the Navy which are popularly known as the "Hush Hush" ships. Their existence has been more or less an open secret for many months, but that fact does not detract from the interest which attaches to the more detailed revelations of M. Rousseau. The new ships are, he says, very long, with immense decks fore and aft. They seemed to lie low in the water, but "perhaps this was an optical effect produced by their length." Amidships there rises a "very squat central castle"—presumably superstructure—flanked by barbettes for "two guns of the biggest calibre." The bows, we learn further, are clipper shaped, this form having "certainly been determined in order to realize very high speed, and, as a matter of fact, these vessels are very swift; much fleeter than the fleetest of pre-war cruisers. These craft—we may call them battle cruisers—are of two types, or, rather, of two dimensions, for their elements of power are, we believe, the same, except as regards protection. As for speed, it is as high on the small as on the big craft, the radius of action having to be the same; and the armament, if it differs in numbers, is the same as regards calibres of the principal and secondary artilleries." These vessels, M. Rousseau continues, have been built since the war, the design having been inspired by the lessons of the war. Laid down in 1915, they have already been twelve months in service, which is justly termed an admirable result of the labor organization in the Royal Dockyards. "Other vessels of the kind are under construction, their dimensions being yet more considerable." The turret is described as containing enormous guns, which fire two rounds per minute, and which, according to the Germans, weigh 96 tons and throw a 1,947-pound shell. M. Rousseau goes on to explain that the two vessels he inspected are sisters, designed to work in company, because they have the same fighting power. "They are capable of surprise actions, against which the enemy cannot guard himself, and their speed is a guarantee against the torpedo. None the less they are fitted with devices to neutralize the explosion as far as possible. They are a proof of the confidence of the British Navy in the powerful surface vessel, capable of heavy hitting, the only one which appears able to assure the mastery of the seas. England," he concludes, "is building many submarines, but the development of this new weapon has not affected the theories which have made the naval power of our Allies, and this is proved by the new building programs, which are the outcome of experience."

There are some people who will probably be surprised to learn that we are still building capital ships, apparently of the largest dimensions, in spite of the submarine, but we ourselves welcome the revelation, and are not in the least astonished at it. In these columns we have consistently upheld the view that "the powerful surface vessel, capable of hard hitting"—in other words, the capital ship—still remains the supreme arbiter of naval warfare, and that the time is not yet come for the capital ship to yield its place to the submarine. This judgment, we are aware, is in direct conflict with the views of several distinguished authorities, including Admiral Sir Percy Scott, who are inclined to pin their faith to the small and cheap submarine weapon, and have adopted, in a modified form, the well-known tenets of the French "Jeune Ecole." In a recent article we quoted the opinion of the late Admiral Dewey, who declined to concede that submarine development had seriously reduced the value of the heavy fighting ship. He did admit, however, that the menace of underwater attack had become serious enough to justify drastic modifications in the design of surface ships, a point on which there is general agreement. To continue building costly leviathans which, however great their gun power and armor protection, were liable to be disabled or sunk by a single torpedo, would be manifestly unwise, and we are convinced that this important feature was duly considered when the new ships of which M. Rousseau speaks were in process of design. In fact, he specifically mentions the devices with which they are fitted to minimize the effect of submarine explosion. After a prolonged naval campaign, in which every weapon has been subjected to the final and exhaustive test of action, it follows that many improvements must have suggested themselves. No doubt the capital ship of today is designed on principles which differ fundamentally in some respects from pre-war practice. But it is clear from M. Rousseau's remarks that the naval authorities of this country have no intention of abandoning the construction of such ships. In the United States, where the lessons of the war have been most carefully studied, not only are heavy armored ships being built in larger numbers than ever, but the size has grown enormously, and battleships of 40,000 tons, and battle-cruisers of 34,800 tons, are either building or projected. Nor has Germany lost faith in the powerful surface ship, for it was recently announced that a new battle-cruiser, named the Graf von Spee, had been launched at Danzig. As long as the three leading Naval Powers, two of them having had forty months' war experience, continue to build these vessels, we may take it for granted that the submarine has altogether failed to substantiate its claim to be regarded as the most potent instrument of combat.

Although it is not yet permissible to publish further details of the new British cruisers, M. Rousseau tells us enough to indicate not only the broad features of the design, but also the tactical function the vessels are meant to fulfill. No type of warship has in modern times been the subject of so much controversy as the battle-cruiser. When the "Invincibles" were launched in 1907 they were severely criticized by many eminent officers. Far too much, it was urged, had been sacrificed to speed, the tactical value of which had yet to be demonstrated, and when from the comparatively modest figure of 17,250 tons for these ships the displacement rose in the "Lion" class to 26,350 tons, the advocates of moderate displacement were speechless with consternation. The increase in size, great as it was, had become essential in order to realize the ideal at which the Admiralty was aiming, *viz.*, extremely high speed combined with the greatest possible artillery power. In all the battle-cruisers designed in this country protection was to some extent sacrificed to obtain these two desiderata. Germany soon adopted the type, but developed it on somewhat different lines. She was content with slightly less speed and a lighter armament, but gave much more attention to armour protection. The war had not been long in progress before the battle-cruiser proved its value. The engagement off the Falkland Islands—so far the most decisive action of the war—was rightly hailed as a triumph for the battle-cruiser, though its success on that occasion was more strategical than tactical, for it was only by virtue of their high mobility that the Invincible and Inflexible were able to cross the ocean at the sustained sea speed of liners, and arrive at Port Stanley in the very nick of time. In the later action of the Dogger Bank, and also at Jutland, the battle-cruiser was found to be more vulnerable than had been suspected, but the fact that it risks disablement or destruction by engaging battleships for any length of time does not discredit the tactical theory which evolved this type. The new British cruisers of which M. Rousseau writes would appear to be the logical development of the "Invincible" archetype. They are, as he says, extremely fast, and their armament comprises a very limited number of exceptionally heavy guns. To find the true origin of the battle-cruiser we must go back forty-five years, and seek it not in England but in Italy. It was in 1872 that the keel of the Duilio was laid at Castellamare, a ship that represented precisely the same tactical idea that resulted in the Invincible of 1907, and the new cruisers now with the Grand Fleet. As originally planned the Duilio and her sister Dandolo were to have displaced 10,401 tons, but actually they were nearer 12,000 tons. They were 341 feet long between perpendiculars, 64¾ feet in beam, and had engines of 7700-7900 indicated horse-power for a speed of 15 knots. The hull was protected by a belt of 21-inch armor, which, however, was only 107 feet in length, thus leaving more than two thirds of the side bare of vertical armor, but a flat deck composed of iron and steel plates ran from end to end of the ship at some distance below the water-line. The side above the main belt had 17¾-inch armor and formed a central citadel, surmounted by two turrets protected by 17¾-inch armor, and each containing a pair of 100-ton guns. These turrets were placed *en échelon*, with the centers at a distance of 7 feet 8 inches from the center line of the vessel, an arrangement that rendered it possible to train three guns parallel with the keel, while all four covered a limited arc on either beam. These were the salient characteristics of a design which attracted great interest in naval circles everywhere by reason of its novelty, and combined in a single ship immense gun power and high speed. The famous Inflexible, laid down in England two years later, was admittedly a modified copy of the Duilio, though in her case great speed was not a conspicuous feature. In Italy the integral idea was further developed in the Italia, an amazing specimen of naval architecture for those days. This vessel displaced over 15,500 tons—several thousand tons more than the largest warship then afloat—was 400 feet long, and was intended to steam at 18 knots, whereas scarcely any of the existing armored vessels were good for more than 14 knots. Like the Duilio, she carried four 100-ton guns in échelonned turrets, but she differed in having no vertical armor at all. The vitals were protected by a 3-inch steel deck, and amidships rose a redoubt of 19-inch steel, to defend the gun positions. In speed the Italia was quite unique among her contemporaries, and this fact, coupled with her ponderous battery, made her, in the opinion of many, by far the most formidable warship in the world. A sister ship, the Lepanto, launched in 1883, was followed in 1887 by the Re Umberto, another vessel of the same generic type, but with the displacement reduced to 13,250 tons, and the armament to four 13.5-inch breech-loaders. On the other hand, the speed was increased to 20 knots, and in place of the central redoubt a thin belt of armor was fitted. Moreover, the échelon system was discarded, and the turrets were placed on the center line, for at that date broadside fire was already recognized as of more importance than end-on fire, which alone had warranted the tactically vicious échelon arrangement.

For many years Italy alone continued to build vessels of the general type described above, for at that time other countries were absorbed in problems of armor, and apparently regarded speed, and even gun power, as secondary considerations; but it must always be placed to the credit of the Italian constructors that they were a generation in advance with their tactical theories. Between the latest British battle-cruisers, as described by M. Rousseau, and the Italia there are no fundamental points of difference, though they are separated by nearly forty years, and a most interesting cycle in naval design is thus completed.

*The Engineer.

Time Zones at Sea

There are several matters of time reform in the air (or on the carpet, as the French say), one of which, at least, will probably be realized in the not distant future, for the scheme is already well advanced. This is a proposal to extend the hourly zone-time system, generally used on land, to the ocean, and the suggestion is that time should be kept according to this system both on the vessels of the Navy and of the mercantile marine. The scheme originated with our French allies, who have decided to adopt it in their Navy, and it has been discussed at an official conference in England by representatives of many important interests. The actual proceedings at this conference have not been made public yet, but there can be no impropriety in giving the substance of a note which appeared in the *Comptes Rendus* of the Paris Academy for July 23.

On board ship there are timekeepers of two kinds. There are chronometers for the purpose of navigation, which naturally show Greenwich time, and there are the clocks in use for the every-day life of the ship, which are set day by day, more or less at the discretion of the captain, but, speaking generally, show the local time of the place where the ship happens to be. It is this latter class of instruments to which the reform is to apply. It is proposed that the clocks on board ship shall always show a time which differs an integral number of hours from Greenwich time. The clocks need not be altered immediately on entering a new time-zone; but this will be left, as before, to be controlled by circumstances. These clocks, however, will always show the time of some hour-zone—preferably that in which the ship then is, and the number of the zone that the clock is then keeping is to be exhibited beside the clock; and in any entry of time made from the clock, in the ship's log or elsewhere, the number of the zone is to be entered. The numeration of the zones was discussed at the conference, and it has been decided that they should be + 1, + 2, + 3 . . . West from Greenwich, — 1, — 2, — 3 . . . Eastward. All this may seem rather unimportant, but the result of the change will be that Greenwich time can be deduced from the clock time quite easily; and it has been decided that in the case of wireless messages the time of sending shall always be given in Greenwich time, which illustrates the purpose of the new scheme. *Summer Time* is to be ignored entirely.

The other reforms referred to above emanate from this. It is proposed in the first place that the astronomical day shall be made to agree with the civil day; or, in other words, that in the National Ephemerides the day shall begin at midnight, which is to be 0 hours, and the hours are to be numbered from 0 to 23. The

alteration of the astronomical day is a very debatable matter, and the Astronomer Royal and Professor Turner are the joint signatories of a letter in the *Observatory Magazine* of this month, which asks for the opinion of astronomers on the point. More than twenty years ago this same question was under discussion, but nothing materialized. The cognate question of numbering the hours of the civil day from 0 to 23, which was also discussed at the earlier date, will probably again arise.—*English Mechanic and World of Science.*

Saving Steel in Ships*

In designing warships or special types of merchant vessels calculations are made to decide whether the vessels will be strong enough for their intended work. These calculations are very complicated and involve a large amount of labor. The ship is treated as if she were a beam supported by her buoyancy, which is equal to her displacement, and loaded with weights made up of her own weight and that of any loads she may be carrying. This gives the bending moment and shearing force at any point in her length.

The value of these factors will vary in accordance with the distribution of the buoyancy and weight, but the maximum bending moment will occur at or near amidships, and the shearing force will have a maximum at about the quarter lengths of the ship. The strength of the section can be estimated at any point so that the stresses acting can at once be determined. Usually if the strength is sufficient amidships it will be so throughout. In special cases, however, the strength is estimated at any doubtful point and the material disposed accordingly. It should, of course, be understood that these calculations are not to be regarded as absolute. They really form a means of comparison between vessels, and it is doubtful if the stresses obtained by this means really represent those actually existing in a vessel at sea.

In ordinary merchant vessels calculations are not required. Registration societies have drawn up tables of scantlings for steel vessels by means of which the necessary strength in any ship can be provided. These tables have been derived to some extent by calculation but for the most part they are based on experience. It is not surprising, therefore, that similar vessels built under different societies' rules vary in strength.

WORK OF THE LOAD LINE COMMITTEE

The greater the displacement of a ship the larger will be the forces acting on her. The question of the relation between draught and strength of ships was very fully dealt with by the Load Line Committee. This Committee estimated the strength of various ships at their amidships sections with steel scantlings as fixed by the four principal registration societies. The values were found to vary, and they were plotted as curves having for their base the length to depth ratio of the ship. Fair curves were drawn for each society, representing the minimum values, and a minimum curve was then drawn which was taken as a standard by the Load Line Committee. It was found that the strength of the section varied directly as the draught of the ship, the beam, and as a factor depending on the length of the ship. A standard of transverse strength was also investigated by the committee and determined in a similar way to the longitudinal strength. It follows, therefore, that in most cases the scantlings at present adopted by the registration societies will give a strength greater than the standard. Hence it is to be expected that some modifications will be brought about in the rules of the societies with the object of reducing the amount of steel in merchant ships.

The rules, however, have a further application which is important. The standard of strength set up by the Load Line Committee refers to vessels running at a draught equal to the maximum laid down by the Load Line rules. Many ships are built the carrying capacity of which is determined by the cargo space available rather than by the cargo weight. Such vessels cannot stow a sufficient weight of cargo to load them down to the maximum permissible draught. In consequence, the forces brought to bear on them are less, and their strength could accordingly be reduced in the direct ratio of their actual draught to the maximum. The registration societies have partly recognized this consideration already. Lloyd's Register will allow a reduction in scantlings for vessels carrying a limited amount of cargo with a fixed freeboard. Germanischer Lloyd specifically state the reduction in scantlings for reduced draught, but fix a maximum reduction which can be applied to the longitudinal and transverse structural parts. These reductions apply to the half length of the vessel amidships. At the ends only half the amount is allowed. The principle used is that the strength of the ship must vary as the draught. Bureau Veritas adopt a similar procedure to the German society, and state that all the midship tabular scantlings, that is the scantlings of the strength parts, may be reduced in the direct ratio of the proposed draught of water to the full draught allowable, while the scantlings at the ends are to be those which correspond with the reduced midship scantlings. A limit below which the scantlings are not to be reduced is fixed.

SUBDIVISION

In addition to the reason already given for many ships running at draughts below the maximum permissible there is now the operation of the International Convention Rules to be taken into account. Any vessel carrying 12 or more passengers comes under this Convention, which fixes the subdivision in accordance with the freeboard ratio—that is, the ratio between the freeboard and the draught. While it is theoretically possible to put a sufficient number of bulkheads into a ship to enable her to run at her maximum draught and still fulfill the Convention Rules, the result will often be the introduction of so many bulkheads into the ship that she would not be satisfactory commercially. In consequence, in order not to diminish unduly the length of holds, fewer bulkheads will be fitted and the draught reduced below the maximum. It will be some compensation for this reduction in draught if the registration societies allow the scantlings to be reduced.

In fixing the scantlings for a ship from the rules of a registration society reference is made only to the principal dimensions, and these take no account of the deck erections. On the other hand, by the Load Line rules the greater the erections the greater can the maximum draught be. In considering Lloyd's rules, for instance, the midship scantlings for a ship with erections will be the same whatever the extent of these, provided the center or bridge erection is not less than the minimum length given by Lloyd's Register for long bridges. Taking a particular ship, say, 510 ft. long, the load draught would be about 31 ft. 4 in. if the bridge was of the minimum length of 102 ft. If the length of the bridge were increased to 306 ft. and a poop and forecastle added, each 64 ft. in length, the load draught would be 33 ft. 1 in. Therefore, although the two ships would have the same strength amidships, the calculated forces brought to bear on the latter would be 5½ per cent. greater than on the first. If the three erections were now merged into one, that is, the ship made into an awning decker, the permissible load draught would be 34 ft. 1 in. Here again the midship scantlings would be unaltered, but the forces acting on the ship would be about 9 per cent. greater than in the first case. If the process of increasing the erections is still continued and a center erection added on the awning deck the load draught must still remain the same, although in this case the strength would have been increased.

TYPES AND FREEBOARD

To fix the scantlings of a ship so that she may be suitable for her work and still fulfil the rules of the registration societies attention should be given to the relation between her draught and depth. An awning-deck vessel must run at a less draught than a similar vessel having an upper deck in the same position as the awning deck. In the first case the load draught is fixed from considerations of strength, but in the second from considerations of reserve buoyancy. The latter vessel, however, can have a greater draught than the former because she is a stronger ship. If the strength of the awning-deck ship is increased her draught can be increased in proportion. At least, this was the rule, but nowadays it is no uncommon thing to find awning-deck ships running at the same draught as full scantling or upper-deck ships. Shelter-deck vessels are of the same strength as awning-deck vessels, and it will be remembered that some time ago the Shipping Controller gave permission for these vessels to run at a load draught equal to that of a full scantling ship, provided certain rules were complied with. The carrying out of these rules, however, did not increase the strength of the vessels.

Perhaps the best illustration of how steel can be saved by careful attention to the relation between the draught depth is given by the case of an awning-deck vessel having a complete deck added over her, the draught at which the vessel is required to run being that given by assessing the freeboard from the awning deck. In the ordinary way the deck over the awning deck—that is, the shade deck—would be taken as an awning deck. This would considerably increase the scantlings, as compared with the assumption that the second deck down is an awning deck. The scantlings for the shade deck would then be the same as for an awning deck. The awning deck itself would be treated as a first deck, and so on. A further reduction in the scantlings would be brought about by the fact that the length to depth ratio can be taken to the shade deck, so that altogether an appreciable weight of steel would be saved.

It is quite clear from what has been said that there are many merchant vessels running at the present time of greater strength than they need be if existing knowledge on the subject were properly applied, and it may be anticipated that after the war a revision of the rules will be brought about which will effect considerable savings of steel.

*Engineering Supplement of the London *Times*.

The First Ferro-Concrete Ship

In the article on ferro-concrete shipbuilding that appeared in the Scientific American Supplement of December 8th the statement is made that on the same day that the Namsenfjord, the first sea-going concrete ship, was launched the lighter Beton I. was put in the water. Mr. N. K. Fougner, the designer and builder of the Namsenfjord, the pioneer in this class of construction, whose name has been so prominently identified with ferro-concrete shipbuilding abroad, writes us that the above statement is incorrect, inasmuch as the Namsenfjord was launched completely equipped on August 2, 1917, and started on her trials a few weeks later, while the launching of the barge at Porsgrund did not take place until some time later, and as it was then in an incomplete condition it had not undergone any tests up to the end of October.

Mr. Fougner is now in this country and has organized a company for constructing vessels after his original designs.

Titanium

Titanium is metallurgically somewhat in the position which aluminium, occupied forty years ago. Very widely distributed, though not generally in large deposits, titanium might be utilized in various ways if the smelting difficulties could be overcome. Chemically titanium stands between carbon and silicon on the one side, and zirconium and the rare earths on the other. It occurs mostly as oxide, TiO_2, alone as rutile, or associated with iron as ilmenite, $FeO.TiO_2$. The chief European deposit is at Kragerö, in Norway; very large deposits of ilmenite are found in the Quebec Province (near Rapid River and Saguenay River), in the United States, India, Ceylon, Nigeria, Queensland and South Australia. The titaniferous iron-sands abounding on the shores of Taranaki Bay, New Zealand, first attracted attention in the British Colonies; but they are unsuitable for the blast-furnace, and even the quite recent attempts at briquetting the ore and smelting it in electric and other furnaces have hardly been successful so far, as we see from the *Bulletin* of the Imperial Institute, vol. xv, No. 1, 1917, which contains a very instructive article on "The Distribution and Uses of Titanium Ores," amply stocked with references. The pig-iron from the titaniferous sands is too rich in phosphorus and sulphur. Earlier attempts made at Norton, in England, to smelt titaniferous iron ores were given up, owing to the pasty condition of the slag and the uncertainty of the ore supply. That uncertainty does not exist at Sanford Hill, in the Adirondacks (New York) and in the Iron Mountains of Wyoming; but the smelting is not prospering, and the replacement of the silicon in the iron by titanium is not liked. Yet rail steel is notoriously improved as to strength and abrasive resistance when about 1.7 lb. of titanium (as iron alloy) is added in the ladle per ton of steel; and ferro-titanium was much used for this purpose in the days of Bessemer steel, though the metal had to be reduced by the aid of aluminium. The action of titanium, which binds the nitrogen in iron to a nitride, is said to be less marked with open-hearth steel; but basic steel has been improved in this way at Osnabrück, at any rate. There are other uses of titanium. The metal filaments have been superseded by tungsten. But the General Electric Company makes arc electrodes of titanium carbide or of a magnetite containing 20 per cent of titanium; yellow titanium pigments are appreciated in ceramics and mixed with asphalt as rust-preventing paints, titanium salts give superior mordants in the textile and leather industries, and the nitride, we may add, is a promising refractory material.—*Engineering.*

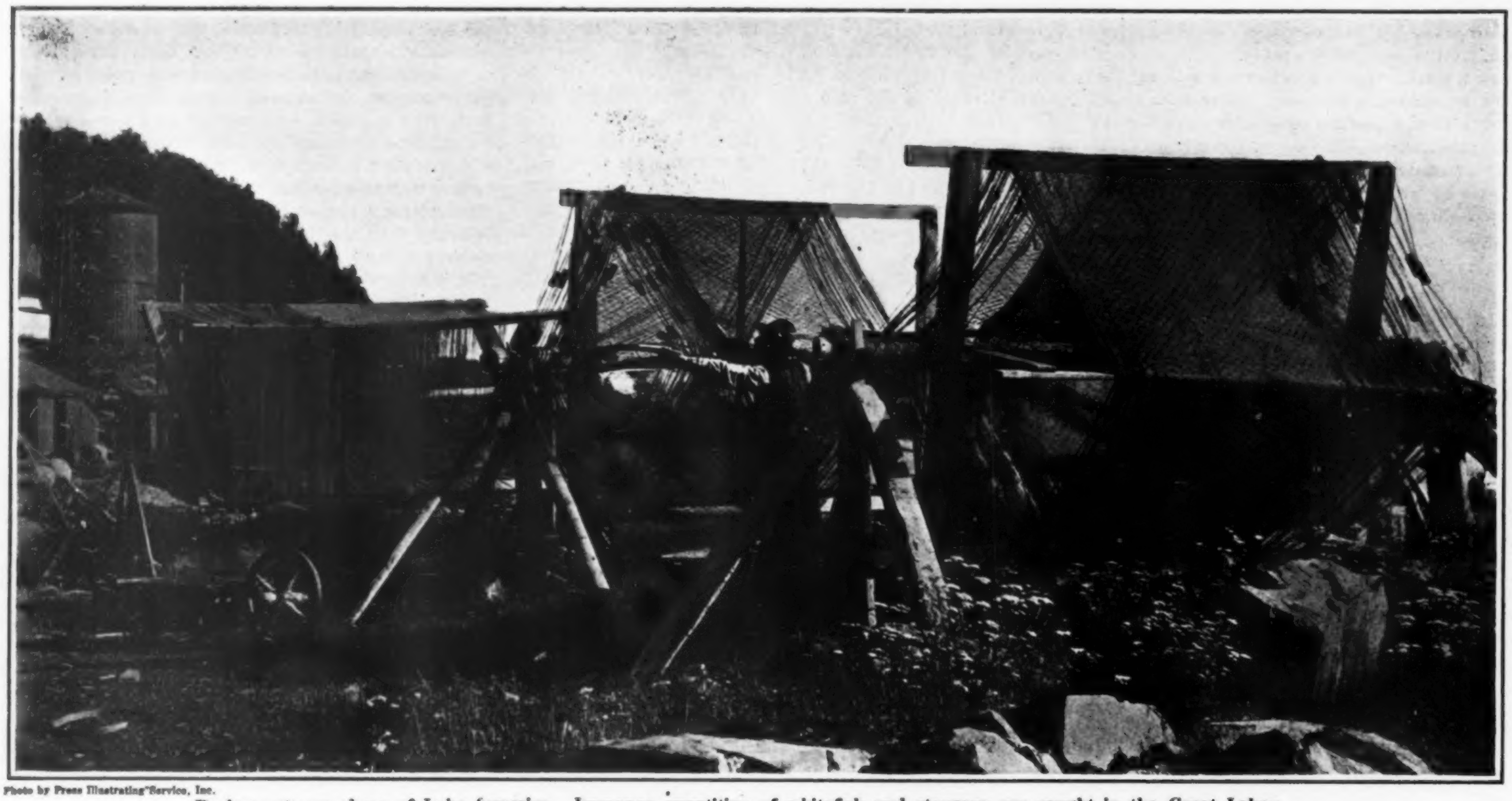


Photo by Press Illustrating Service, Inc.

Drying nets on shore of Lake Superior. Immense quantities of whitefish and sturgeon are caught in the Great Lakes

Let's Eat Fish

FOOD ADMINISTRATOR HOOVER says we ought to eat more fish, and up in Canada Food Commissioner Hanna says the same thing. They are trying to make fish a big item in the North American war menu.

The United States Government Bureau of Fisheries is fostering the raising of fish by furnishing eggs free of charge from its numerous hatcheries. It is urging the people to substitute fish for meats, and will furnish recipes for the asking. Government experts know all about fish from the time they are hatched until they are served on the dining table, and are ever ready to supply information to individuals.

The bureau is calling attention to whales, dolphins and porpoises as first-rate food, and many other fishes hitherto regarded as unfit for the table.

The United States, including Alaska, is now producing $75,000,000 worth of fish annually. Insular possessions, $15,000,000. Canada, with population of 7,000,000, is producing about $40,000,000 worth, the main items of which are $15,000,000 worth of salmon on west coast, and $10,000,000 cod, haddock, halibut, bluefish, weakfish, etc., in Nova Scotia.

Canadians are eating more fish than ever before, and consumption there is expected to increase more rapidly in the future. Talk there of two fish days a week, which idea is urged upon the people of this country by the United Master Butchers of America. Hotels here and in Canada are serving more fish and less meat. Big Canadian Pacific Railway system is serving as much fish as meats in its dining cars and hotels, and lines in this country beginning to follow suit.

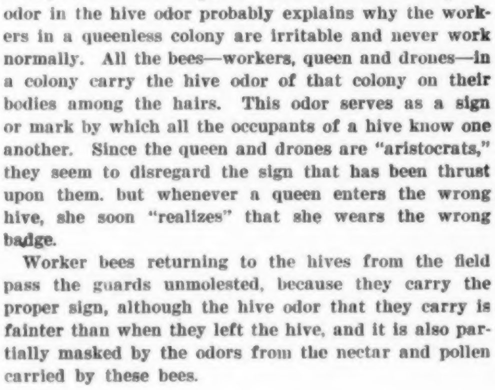
The United States food experts say fish is just as good as many of the meats we eat—just as nourishing—and this statement is backed up by the fact that hundreds of thousands of farmers and other men doing hard labor eat canned salmon from twice to six times a week.

Odors Emitted by Bees

IT is certain that a queen gives off an odor, and it seems reasonable that the odors from any two queens would be slightly different. All the offspring of the same queen seem to inherit a particular odor from her. This odor, called the family odor, perhaps plays little or no part in the lives of bees, for it is certainly masked by the other odors. Drones seem to emit an odor peculiar to their sex, but little can be said about it. It seems certain that each worker emits an individual odor which is different from that of any other worker. It is also probable that the wax generators and nurse bees emit odors slightly different from those of the field bees.

Of all the odors produced by bees, the hive odor is probably the most important. It seems to be the fundamental factor or principle upon which the social life of a colony of bees depends, and perhaps upon which the social habit was acquired; without it a colony of bees could not exist. The hive odor is composed chiefly of the individual odors from all the workers in a hive, and is supplemented by the odors from the queen, drones, combs, frames and walls of the hive, etc. From this definition it is easily understood why no two colonies have the same hive odor. The hive odor of a queenless colony is perhaps considerably different from that of a colony which has a queen. The absence of a queen odor in the hive odor probably explains why the workers in a queenless colony are irritable and never work normally. All the bees—workers, queen and drones—in a colony carry the hive odor of that colony on their bodies among the hairs. This odor serves as a sign or mark by which all the occupants of a hive know one another. Since the queen and drones are "aristocrats," they seem to disregard the sign that has been thrust upon them, but whenever a queen enters the wrong hive, she soon "realizes" that she wears the wrong badge.

Worker bees returning to the hives from the field pass the guards unmolested, because they carry the proper sign, although the hive odor that they carry is fainter than when they left the hive, and it is also partially masked by the odors from the nectar and pollen carried by these bees.



A big catch of tuna

Bees kept in the open air for three days lose all the hive odor carried on their bodies, but each bee still emits its individual odor. When a colony is divided the hive odor in each half soon changes so that by the end of the third day the original colony possesses a hive odor so different from that of the other half of the colony, that when the workers are removed from the two new colonies and are placed together in observation cases, they fight one another as though they had been separated all their lives.

While a foreign hive odor calls forth the fighting spirit in workers, the queen odor always seems pleasant to workers regardless of whether the queen belongs to their hive or to another hive. Even though the queen odor forms a part of the hive odor, it is probable that this odor to the workers stands out quite prominently from the hive odor. That workers do not miss their queen for some time after she has left the hive indicates that her odor thoroughly permeates the hive odor and that whenever this odor grows faint the workers "know" that she is not among them.

There has been much speculation concerning the ruling spirit or power in a colony of bees. The present writer is inclined to believe that a normal hive odor serves such a purpose. The hive odor is a means of preserving the social life of the bees from without, and the queen odor which is a part of it insures continuation of the social life within. As already stated the workers "know" their hive-mates by the hive odor they carry. This odor insures harmony and a united defense when an enemy attacks the colony. The queen odor constantly informs the workers that their queen is present. Even though she does not rule, her presence means everything to the bees in perpetuating the colony. Thus by obeying the stimuli of the hive odor and queen odor, and being guided by instinct, a colony of bees perhaps could not want a better ruler.

All insects apparently emit odors, but only those of honey-bees and ants have been carefully studied; while the family odor among ants seems to play an important role, it is probably of little or no use among bees, because the hive odor has assumed such an important part in recognizing the members of the same or of a different colony. The progressive odor among ants is perhaps more highly developed than it is among bees, because the duties of ants are more varied than are those of bees and since slavery among ants is common.—Abstract from Smithsonian Miscellaneous Collections Vol. 68, No. 2, "Recognition Among Insects" by N. E. McINDOO, Ph.D.

Mission Grapes In Ireland

A LITTLE while ago a much traveled sea captain was in Ireland. His eye was attracted by some grapes which he was certain were similar to those he had known in California as "Mission" grapes; so called because they were introduced into that country by Spanish missionaries. Being interested in the subject, he pursued his inquiries, and found that his surmise was correct. The grapes were grown from cuttings of vines which formed part of the cargo of the Spanish Armada, hence their similarity to those of California, both being of Spanish origin. This beautiful fruit flourishes in a sheltered valley on the western side of Lough Swilly, where no frost has nipped the vines for five years, although frequently snow is visible on the distant hills.

Smoking haddock to make finnan haddie

Photos by Press Illust. Service, Inc.

Fish drying at Digby, Nova Scotia

Eye Protection and Sight Filters

If our ancestors were liable to strain their eyes by having to work in insufficiently illuminated rooms, the development of electric lighting and the general industrial development of our age are more apt to endanger our sight by the effect of intense and trying illumination, and we have learned to understand that the greatest dangers to our eyes lurk in radiations which are invisible in more than the ordinary sense. In the strict sense all radiations are of course invisible as long as they are not stopped, absorbed or reflected in some way; the "optically empty" medium does not betray the rays of light passing through it, and would probably not suffer from the light if such a medium were endowed with consciousness. But the different organs of our eye may suffer before we become conscious of light sensation, and the investigation of the physiological effects of light is difficult and fraught with danger to the investigator. When we wish to consider these phenomena we must not speak of light generally, but must define and classify the radiations, and the simplest way of doing this is to classify them as to wave-lengths. To arrive at a conception of wave-length we must split the ray or beam of light up into something which need not be much more directly present in it than the greenish poisonous chlorine gas of our laboratories is present as such in the salt we put into our soup. The spectrum shows the eye the beam of white light spread out into a luminous band shining in brilliant colors, and physical and chemical tests teach us that the visible band is only a small portion of the invisible band, and that the apparently simple ray is anything but homogeneous. We measure the wave-lengths in Angström units ($1AU=10^{-10}$ m.$=10^{-8}$ cm.$=1$ micromillimeter, or millionth of a millimeter $=1\ \mu\mu$), or in microns, μ ($u=0.001$ mm.). Measured in μ, yellow light has the wave-length 0.59, and the visible spectrum ranges from about 0.38 (violet) to 0.75 (red). Radiations of wave-lengths shorter than violet light are known as ultra-violet, Schumann rays (0.1 μ) and Lyman rays; then follows a long, relatively unexplored gap, until we come to Röntgen rays, of the order of 0.0001 μ or less. Infra-red waves longer than red rays, on the other hand, have actually been measured to lengths of more than 100 μ (0.1 mm.); with waves hundreds and thousands of millimeters in length we pass into the range of electric radiation; radiotelegraphy makes use of waves kilometers in length.

When the temperature of the source of radiation is raised, the energy of the radiation, which in sunlight has its maximum at 0.46 μ, is more and more concentrated in the rays of shorter wave-lengths and higher frequencies, and it seems natural that those radiations, the ultra-violet rays and X-rays, should be more injurious to the eye than the longer visible rays. Yet the analogy of alternating electric current would not support that argument; high-frequency currents can be borne at tensions which would be fatal with low-frequency currents and continuous currents. If the eye consisted merely of the lens—which bears its name crystalline lens with some justification—one might further expect that wave-length and frequency would, from the safety point of view, make little difference. But our eye is built up of exceedingly complex and delicate organs, which light affects in different, little-understood ways. When lecturing last summer before the Optical Society on "Light Filters for Eye Protection," Mr. L. C. Martin, B.Sc., of the Imperial College of Science, drew attention in this connection to the experiments which Dr. E. K. Martin made on the eyes of freshly-killed rabbits. Such experiments are based upon the assumption that radiations which are not absorbed by an organ are incapable of harming that organ, an assumption which is probably correct in principle, but may be vitiated in practice by the fact that exact quantitative absorption tests are hardly possible. Studying the effects of the ultra-violet rays from an iron arc and a quartz spectrograph on rabbits' eyes, Dr. Martin found that the cornea was fairly transparent, but stopped rays shorter than 0.295 μ completely; that the lens began to absorb at 0.38 μ, and absorbed completely at 0.35 μ; and that the vitreous humor (in a layer 3-16 in. thick) seemed transparent to short waves, but had an absorption based between 0.28 μ and 0.25 μ. Exposure of the eyes of living animals to ultra-violet rays (from mercury arcs) caused corneal opacity if of sufficient intensity and duration. As now the solar spectrum stops at about 0.29 μ, ordinary daylight should be incapable of harming the cornea, which covers the whole front of the eye. We all know that we should not stare into the sun; the blue light from the sky is not injurious, but the scattered daylight of a haze and that reflected by water and foliage may contain all the original solar radiations. The eye organs mentioned, moreover, act as a lens system, concentrating the light on certain small areas of the retina, which is exceedingly sensitive.

The action of infra-red rays is less clear. Sir W. Crookes found that the radiations from molten glass consist essentially of long waves and do not contain X-rays. That the workers at glass furnaces and blast furnaces, much exposed to heat radiation, do develop cataracts, seems to be due to infra-red rays. As water absorbs infra-red radiation, it may be presumed that the refracting media of the eye would absorb rays longer than 1 μ. Whether the injurious effects produced are merely the results of a rise of temperature, consequent upon absorption within the eye, effects which the hot, dry atmosphere and risk of draughts near furnaces would accentuate, or whether the infra-red rays have effects of their own, is not understood; but the protection of the eye has to guard against infra-red as well as against ultra-violet rays. There are other things which irritate and fatigue the eye: unsteady, flickering illumination; sharp contrasts of light and darkness and of objects in different colors, to which the eye, which is not achromatic, cannot adapt itself; bad definition of images or glare produced by microscopes and telescopes; an atmosphere impure with dust and vapors—light filters cannot meet all these troubles.

The eye protection which spectacles can afford is necessarily imperfect lest the spectacles, like the gas masks, become a nuisance which the worker rather dispenses with. Up till recent years light filters were essentially smoky glasses or cobalt glasses, intended to stop either the glare or the ultra-violet. The former object was generally realized, with the result that the wearer of the spectacles complained about insufficient light. The ideal light filter would stop all injurious radiations without much diminishing the general brightness. In testing light filters from this point of view Mr. L. C. Martin made use of three apparatus: that of Messrs. Hilger (a quartz spectograph for ultra-violet light, in which the original beam and a beam sent through the specimen are compared, rotating sectors being interposed for varying the exposure); the apparatus of Sir William Abney for examining the visible spectrum; and the apparatus of Professor H. L. Callendar for the infra-red. Mr. Martin's apparatus were not well suited for determining the absorption at either end of the visible spectrum, especially near 0.76 μ in the infra-red, and the measurements in these regions might be wrong by 2 per cent. or 3 per cent., whilst the other measurements were probably correct within 1 per cent. The glasses which he examined were always plane and well polished, about 2 mm. in thickness generally, but varying much in thickness; the results were calculated for a thickness of 2 mm. The glasses tested were: neutral glasses, *i. e.*, glasses of a grey smoke tint; various glasses of Sir William Crookes, who four years ago presented a paper on these researches, which he is still continuing, to the Royal Society; fieuzal glasses, the greenish-yellow tint of which is probably due to chromium; Hallauer glasses, of a greenish smoke tint; signal green, red and yellow glasses. Some dyed celluloid and gelatine films were also tested.

Mr. Martin gives his results chiefly in tabular form and in transmission curves for the different regions of the spectrum without much general summary. The time for generalization has hardly come, in fact. The ideal spectacles which will keep out the glare of the sun, arc and snow, and which will protect the man in front of the furnace as well as the experimenter with ultra-violet rays, is not likely to be discovered, apparently; absorption at both ends of the spectrum and transparency in the visible region are difficult to combine. Neutral glasses which contain various metallic oxides Mr. Martin found to be ineffective in both extremes, especially in the infra-red, unless too opaque generally. The Crookes glasses are made by Messrs. Chance and other firms; Sir William has no commercial interest in them. The several hundred glasses he has studied are all soda glasses, containing some lime, up to 25 per cent. of ceria—which gives a colorless glass if pure, but is not quite free from didymium generally, which introduces a faint reddish tint—and further, the oxides of the ferro-metals (Fe, Ni, Co, Cr, also uranium). What Mr. Martin calls the "Crookes spectacle" glass is presumably his glass No. 185, of an almost colorless tint, faintly grey, in thick layers orange, which Mr. Martin found to absorb rays shorter than 0.36 μ and to transmit 85 per cent. of the visible and 65 per cent. of the infra-red, especially beyond 2 μ. It appears to be a very good glass for general use, and has already become popular. Some fieuzal and Hallauer glasses would rank next to this glass, though they did not appear so effective in the infra-red. Both these styles are made in different grades. The Crookes glass No. 202 (neutral tint, 5 per cent. ferric iron, a little cobalt) had a very strong absorption near 1.3 μ and in the further infra-red, but did not transmit more than 27 per cent. of the visible spectrum. The Crookes glass 246 (tint sage-green, containing 10 per cent. of ferrous oxalate and a little charcoal and red tartar) transmitted only 20 per cent. and 7 per cent. respectively of the visible and infra-red rays and little ultra-violet, and proved most efficient for heat-ray absorption. Signal-green glasses (containing cupric oxide) resembled the glass 202; they had a strong absorption near 1 μ, which rays are prominent in the sunlight. Most of the various celluloid and gelatine films examined, some of which were collodion-coated, transmitted less than 10 per cent. of the visible spectrum, though their organic dyes also absorbed ultra-violet and infra-red rays.

Some of these delicate films require protection for themselves. That applies likewise to thin laminæ of biotite (a smoky-brown mica) and other minerals, and to the metallic films of gold and silver produced (by chemical reduction or by kathode volatilization) on glass. Silver films, in particular, make excellent filters for heat rays, and there is, on the whole, no longer any lack of suitable light filters for special purposes, though the ideal light filter for general purposes may not yet have been found. That, after all, is not a serious drawback. We always want special clothing and special tools for special work, and what is never grudged in sport should not be grudged in industrial pursuits.—*Engineering.*

The Tungsten Deposits of Southern Rhodesia*

There seems to be a general opinion that the tungsten deposits at Essexvale consist only of so-called alluvial or rubble wolframite, and that reefs have not been found. This is not true. Some reefs have long been known, and the excavation of the rubble has led to the uncovering of others, which, so far as can be judged without actual sampling and development, offer good prospects for mining. But hitherto there has been a strange reluctance to undertake mining operations on the reefs, whilst the work on the rubble has been largely desultory.

The known tungsten reefs lie within an east and west rectangular block of country of about nine and a half square miles area, immediately to the north of Essexvale Siding and mainly west of the railway. The reefs extend from the neighborhood of "The Ranche" (2¾ miles northwest of the siding) to the native church (1½ miles northeast of the siding). Sixteen distinct reefs are known, eleven of which have had a little work done on them from time to time.

History

The deposits were first prospected in 1906. In the ensuing two years a fair amount of ore was produced, but in 1909 the production ceased. A little interest was again taken in the deposits in 1912-13, but there was no production in 1914-15. At the end of that period a local syndicate extensively sampled some thousands of tons of rubble and made trial crushings. The grade was found to be just too low for profitable working by the methods then employed. During 1916, however, determined efforts have been made by other workers to test the rubble of two restricted areas.

Altogether about 85 tons of concentrate, valued at £7,165, has been marketed. The returns for 1916 are 2½ tons, valued at £467. This was produced by one worker with a few natives in a 5-ft. rotary diamond washer, and by one man on another claim, who handpicked rubble and recovered 1,600 lb. of wolframite.

The prospecting done on the few reefs that have been opened has nowhere been for more than a few feet below the surface. This may be due chiefly to the fact that the deposit upon which serious prospecting work has been undertaken is from its nature the least likely to prove profitable.

Geology

The known tungsten-bearing tract of country occupies the central portion of an irregularly oval mass of granite about 8 miles long and 5 miles across at the widest part. The long axis of the mass trends northwest to southeast. This granite body forms the floor of a wide depression which is traversed by two permanently flowing streams, one of which is known as Fern Spruit. The granite appears to pass beneath the surrounding rim of epidiorite and felsite hills. The soil is a pale red sandy loam. There are very few exposures excepting in the streams and an occasional small but bold granite kopje. The granite almost wherever seen is coarse-textured and massive—that is, not schistose. It is a hornblende granite, and is thus different from the large granite masses of Rhodesia. Patches of epidiorite, probably inclusions of country rock, and dykes and other bodies of felsite are occasionally encountered, particularly near the eastern edge.

The tungsten reefs consist of greisen composed chiefly of a soft greenish-yellow mica, or of mica, fluorspar, topaz and secondary felspar. This rock weathers soft and rusty brown. The greisen has arisen by the action of vapors on a porphyry or aplite (fine-textured white granite free from hornblende and mica). With the greisen of each reef is a variable amount of rather white glassy quartz forming strings or large lenses in the greisen, and evidently connected with the greisenization—that is, deposited at the same time and by the same agency as the mica, fluorspar, topaz, tourmaline, chlorite, wolframite and scheelite of the greisen.

The constant presence of the quartz lenses as part of the greisen bodies is a great help in recognizing the presence of the greisen. Those parts of the greisen which contain little or no quartz very rarely crop out, and thus may easily escape discovery. No tungsten reefs have been found without the quartz, although it is quite conceivable that such exist.

The quartz strings expand into lenses exceeding 20 ft. in width, and thus make low hillocks such as those at "The Ranche" homestead; again two-thirds of a mile to the southeast of this, and at the native church a mile and a half northeast of Essexvale Siding.

The reefs vary from 200 yards to about a mile long. The two most promising reefs exposed are respectively about a mile long and half a mile long so far as proved. These are the Rhoda reef in the northeastern portion of Plot 27, and the reef running through the Lunar and Moon blocks near the common boundary of Plots 37 and 38.

With one exception the reefs examined strike east to west and dip north at angles varying between 30° and 55°. The reef on Plot 4 strikes northwest to southeast and dips northeast at 53°.

The width of the reefs is, of course, variable owing to the lenses of quartz. Apart from the quartz lenses, the width averages three feet and is surprisingly constant.

In each instance the country is coarse massive hornblende granite without signs of shearing or faulting between the reef and the country. It appears, therefore, that the aplite was injected along master joint planes caused by the contraction of the granite on consolidating, and not in fissures caused by faulting. This may have an important bearing on the persistence of the greisen bodies below the surface. In a few instances the mica greisen has a slightly schistose appearance. In a few places greisenization of the country is suspected, but this is on a small scale only, and no tungsten ore has been discovered in it.

With the exception of the Union Jack reef in the northwest corner of Essexvale Reserve, the aplite has been completely greisenized so far as can be judged by the small amount of reef exposed. At the Union Jack the intrusion exceeds 6 ft. in width, but about a third of it consists of white aplite apparently ungreisenized.

The block upon which most work has been done differs from the above blocks, which may be taken to be normal. The occurrence in question is situated on Tungsten Kopje, a prominent hill of massive hornblende granite with a low ridge extending about 300 yards to the east and a longer one to the west.

The fact that a large amount of float wolframite occurred immediately around the hill led to prospecting on the hill, with the result that a stockwork deposit was discovered extending along the eastern and western ridges and on the north flank of the hill.

Throughout the massive hornblende granite of this zone streaks and seams of aplite containing gashes of quartz are scattered rather sparsely and quite indiscriminately. These seams run in all directions and at all angles; many are nearly flat, but some are vertical; they make small saddles in several places, but pursue irregular courses, and expand and die out quite irregularly. They average a few inches wide and in no instance exceed a foot. None are traceable for more than a few yards. The greisen always carries streaks of quartz and occurs on one or both sides of the latter. The aplite varies in degree of greisenization. In some parts the greisen consists of sugary quartz and pyrite with very fine wolframite scattered through it but invisible to the naked eye. Such a rock weathers brown and strongly resembles sandstone. It is always present in the rotary concentrate. In other parts the greisen consists chiefly of a soft yellow mica.

At the southwest end of this deposit a body of greisen about 6 ft. wide, striking north to south and dipping about 40° E. has been opened and afforded rich patches of wolframite.

Minerals of the Greisens

The minerals detected in the greisens comprise quartz, soft yellow mica, felspar, dark green chlorite in rosettes, black tourmaline, pyrite (altered to cubes of limonite at the surface), fluorspar (blue, mauve, green, white and colorless), topaz (pale brown and colorless), galena (rather rarely), pyrrhotite, wolframite and scheelite.

Small quantities of each of these occur in the quartz. Here and there a bunch or streak of any one of them, including the tungsten minerals, lies in the quartz. The distribution of the minerals in the quartz or in the altered aplite is, in fact, generally patchy, as is always the case in greisens. Coarse aggregates of any one mineral are occasionally noted—for example, single aggregates of very large wolframite crystals weighing 235 lbs. and 157 lbs. are said to have been found at the stockwork deposit, and similar groups of crystals have been obtained at the Lunar Block (the specimen in the Rhodesia Museum weighing 172 lbs. coming from here). Pieces of wolframite weighing up to 8 lbs. are not uncommon, and groups of pale, pinkish scheelite crystals measuring 3 in. or 4 in. are to be found. The two tungsten minerals are commonly intergrown; but in spite of this and of the fact that scheelite, containing, as it frequently does, several per cent. more tungstic oxide than wolframite, may be worth several pounds sterling per ton more than the wolframite, it was found that the scheelite was neglected by the workers—in fact, considerable trouble was taken by them to separate it from the wolframite and reject it.

Scheelite is a mineral very easily recognized, and the natives engaged in panning the concentrate should be taught to know it. Although it is not unlike quartz so far as color is concerned, being white, pinkish or yellowish, its characteristic greasy lustre, softness (it is easily scratched by the knife or by quartz), and heaviness are properties which differentiate it sufficiently from any of the minerals with which it is associated. If boiled in dilute hydrochloric acid it becomes coated with bright yellow powder soluble in alkali.

Among the dark minerals got in the concentrate, magnetite may be recognized (and separated) by the magnet, and limonite by being in brown cubes. Coarse and moderately fine wolframite is easily distinguished from the other black minerals by its greater specific gravity and chocolate-brown streak; it breaks into flat slabby pieces with lamellar structure owing to the presence of a single perfect cleavage; the flat surfaces are bright and shiny (submetallic to resinous lustre), whilst the cross fractures are dull. Ilmenite, which is rather abundant, is very fine round grains in the concentrate of the rubble, is difficult to distinguish from fine wolframite by simple tests, and this fact had led to the rejection of the finest concentrate.

In addition to the minerals common to greisen, the presence both in the stockwork and in the veins of galena, pyrite, pyrrhotite and presumably gold, together with the large amount and constant presence of a kind of quartz which is indistinguishable from the ordinary vein quartz of gold deposits, suggests that the Essexvale tungsten deposits are not normal greisens, but to some degree assume the characters of the gold-quartz vein type of deposit. In fact, they appear to form a connecting link between the two types. This theory is borne out by the character of the mineralization of the country rock alongside the greisen streaks in the stockwork deposit. The rock is pyritized (pyrite and pyrrhotite), and the felspars altered to sericitic aggregates.

The richer patches of rubble lie within 100 yards of the greisens on the steeper ground and within about 25 yards on the flat ground.

Tests of this rubble indicate that the yield of wolframite (the scheelite, as noted above, being rejected) varies from 2 lbs. to 8 lbs. per ton. In this estimate the occasional lumps of coarse wolframite are not included, and fine wolframite and scheelite in lumps of rock and free are also not included, since they are rejected.

In the instance of the western end of the Lunar Block reef, it was stated that early in 1916, 1,600 lbs. of wolframite was picked up from the surface by hand without any appliances, without even a prospecting pan, notwithstanding that the ground had been broken, turned over and picked on at least one previous occasion.

Where the rubble is being more thoroughly tested, the ground, made up of angular quartz fragments, brown-weathered greisen and sandstone-like aplite in a matrix of red loam, is hand-jigged on rocking screens, the coarse wolframite being handpicked from the screens. The fines are concentrated in a 5-ft. rotary diamond washer, which recovers the tungsten minerals and even the fine heavy minerals. The concentrate is then panned by hand. The coarse wolframite (pieces over ½ in.) are picked by hand and the fines repanned. Any coarse wolframite with adhering quartz is pestled and panned. The coarse and medium concentrate so obtained is remarkably clean wolframite. The finest concentrate consists of wolframite and scheelite, with a certain amount of quartz, felspar, epidote, hornblende, mica, zircon and tourmaline, together with a trace of gold, and a fairly large quantity of ilmenite, limonite cubes, and magnetite. The finest concentrate

* Reprinted in the *Journal of the Royal Society of Arts* from the *Bulawayo Chronicle*, May 18th, 1917.

is rejected under existing circumstances, but on a larger scale of operations concentrating tables and magnetic separators may be expected to give profitable results.

On the Qualitative Separation and Detection of Gallium*

By Philip E. Browning and Lyman E. Porter

[Contribution from the Kent Chemical Laboratory of Yale University—cccxi.]

GALLIUM, discovered in 1875 by Lecoq de Boisbaudran,[1] is found in nature most closely associated with the elements aluminum, iron, manganese, zinc, lead and indium.[2]

Analytically it falls into the aluminum group. It may be separated from the bases giving sulphides in acid solution by hydrogen sulphide; from nickel, cobalt, zinc, manganese, the alkali earths and the alkalies by ammonium hydroxide in the presence of ammonium chloride; and from iron, titanium, thallic thallium, uranium, indium, and the rare earths by sodium hydroxide in excess, in which reagent the hydroxide of gallium is soluble. In the ordinary course of analysis it appears in the group containing aluminum, beryllium, chromium and vanadium. From the last mentioned two elements it may be separated by ammonium hydroxide after their oxidation to the acidic condition.

This narrows the problem of separation down to the separation from aluminum and beryllium; and the practical absence of beryllium from products containing gallium leaves the most important separation, that from aluminum.

Lecoq de Boisbaudran, in a series of articles published soon after the announcement of his discovery,[3] suggested many methods of separation from the other elements, and recommended especially for the separation from aluminum the use as a precipitant[4] of potassium ferrocyanide in the presence of strong hydrochloric acid to about one-third of the volume of the solution.

In previous papers[5] one of us has shown that silver, lead, zinc, copper and indium have been successfully separated from gallium by various applications and modifications of known methods. The object of this paper is to give the results of some work upon the application of potassium ferrocyanide to the separation of gallium from aluminum and beryllium, and to describe the outcome of experiments upon the delicacy of the test for gallium by the ferrocyanide method, upon the decomposition of the ferrocyanide when formed and upon the application of strong hydrochloric acid to the separation of gallium and aluminum.

It was found that when solutions containing about 0.1 grm. of aluminum or beryllium were strongly acidified with hydrochloric acid and treated with potassium ferrocyanide no precipitation took place, while 0.001 grm. of gallium in the presence of 0.1 grm. of aluminum was easily precipitated and detected at once. Amounts of gallium as small as 0.0001 grm. could be detected after the solution had been allowed to stand an hour or so. These tests were generally made in a volume of liquid from about 5cm³ to 10cm³, of which from one-quarter to one-third was strong hydrochloric acid.

With traces of zinc present, the use of potassium ferrocyanide as the precipant may lead to erroneous conclusions, because zinc ferrocyanide is almost as readily precipitated as the gallium. The presence of zinc may be avoided by the careful application of the ammonium chloride and ammonium hydroxide process. Should, however, traces of zinc remain, we have found that they may be satisfactorily detected and removed by treating a sodium by hydroxide solution with hydrogen sulphide, which removes the zinc without precipitating the gallium. The filtrate, which must still be alkaline, is acidified, and free hydrogen sulphide removed by boiling. The sulphur is oxidized by hydrogen dioxide in sodium hydroxide solution, and the boiling is continued to remove the excess of hydrogen dioxide. The solution is then acidified with hydrochloric acid and the usual ferrocyanide test may be made for gallium. Solutions were prepared containing gallium and zinc and were analyzed by the experimenter without knowledge of the content. The results follow:

Issued	Found
(1) 0·001 grm. Ga	Zn absent, Ga present
(2) 0·001 grm. Zn+0:001 grm. Ga	Zn present, Ga present
(3) 0·001 grm. Zn	Zn present, Ga absent
(4) Distilled water	Zn absent, Ga absent
(5) 0·002 grm. Zn	Zn present, Ga absent
(6) 0·050 grm. Zn	Zn present, Ga very faint indication
(7) 0·050 grm. Zn+0:001 grm. Ga	Zn present, Ga present
(8) 0·050 grm.Zn+0:0002 grm.Ga	Zn present, Ga present

The faint indication of the presence of Ga in experiment (6) seemed to indicate a trace of that element in the zinc. It is of interest to note that this indication was not obtained until the solution had stood twenty minutes, while in experiment (8) the test for the gallium was unmistakable and practically immediate.

A number of reactions were investigated leading to the decomposition of the gallium ferrocyanide and the recovery of the gallium as the hydroxide, such as treatment with bromine and with nitric acid, and fusion with sodium peroxide and with ammonium nitrate. The most satisfactory proved to be fusion with ammonium nitrate, which destroyed the ferrocyanide radical, and subsequent treatment with sodium hydroxide, which precipitated the ferric hydroxide and left the gallium in solution, from which the hydroxide could be readily precipitated by adding ammonium chloride in excess and boiling.

Gooch and Havens have shown that iron may be separated from aluminum by saturating solutions containing these elements with hydrochloric acid gas, adding ether and again saturating. The chloride of aluminum is completely precipitated by this method, and the iron remains in solution. This process was applied successfully to the separation of aluminum from gallium. The presence or absence of gallium may be determined by evaporating the filtrate to dryness on a steam bath and dissolving the residue in dilute hydrochloric acid. This solution, which is free from aluminum, may be tested for gallium by means of potassium ferrocyanide. The following series of unknown solutions was tested by this method, the aluminum chloride used having been purified by the hydrochloric acid precipitation:

Issued	Found
(1) 0·0005 grm. Ga	Al absent, Ga present
(2) 0·1 grm. Al	Al present, Ga absent
(3) 0·1 grm. Al+0:0005 grm. Ga	Al present, Ga present
(4) Distilled water	Al absent, Ga absent
(5) 0·02 grm. Al+0:001 grm. Ga	Al present, Ga present
(6) 0·0001 grm. Ga	Al absent, Ga present

During the first trial of this method aluminum nitrate was used in hydrochloric acid solution. and it was found that no precipitation took place with potassium ferrocyanide. After treatment with the hydrogen chloride gas and evaporation, however, an indication of gallium was found. This led to an investigation which showed that there was some gallium present in the aluminum nitrate, but that the nitric acid formed by dissolving it in hydrochloric acid was sufficient to prevent the precipitation of the gallium as the ferrocyanide. In the evaporation process the nitric acid is destroyed and the test becomes very delicate.

An investigation was then made of the effect of nitrates in general on ferrocyanides. It was found that when one drop of potassium ferrocyanide is treated with 0.4 grm. of ammonium nitrate in the presence of 6cm³ of 1:2 hydrochloric acid it is oxidized completely to the ferrocyanide within two minutes, as may be shown by the use of a ferric salt and a ferrous salt. If 0.2 grm. of ammonium nitrate is used under the same conditions, the ferrocyanide is broken up in less than an hour, while if only 0.1 grm. of ammonium nitrate is used a longer time is required, but completely oxidation finally takes place. Other experiments showed that 0.0001 grm. of gallium cannot be precipitated as the ferrocyanide in 5cm³ of dilute nitric acid, whereas it presence of 3 drops of dilute nitric acid, whereas it is readily precipitated in the absence of it. It was further found that if 0.0001 grm. of gallium is precipitated and 1cm³ of dilute nitric acid is added, the precipitate is decomposed and dissolved within forty-five minutes. It is thus seen that in detecting gallium by the ferrocyanide method care must be taken to have no nitrates or nitric acid present, and that these may be successfully removed by evaporation with hydrochloric acid.

* *Am. Jour. of Science*, ii, 416, 1896.

[1] Compt. rend. (Paris), lxxxi, 493.

[2] Boulanger and Bardet, Compt. rend. (Paris), clvii, 718; Hartley & Ramage, Jour. London Chem. Soc., 1897, 533, 547; Hillebrand and Schnerrer, Ind. Eng. Chem., viii, 225.

[3] Comp. rend. (Paris), xciv, 1154, 1228, 1439, 1628; xcv, 157, 410, 503, 1192, 1332; xcvi, 152, 1696, 1838; xcvii, 142, 295, 522, 623, 730, 1463.

[4] Comp. rend. (Paris), xcix, 526.

[5] Browning and Uhler, this Journal, xli, 351, Apr. 1916; Uhler and Browning, ibid., xlii, 389, Nov. 1916.

A Note on a Possible Explanation of Erratic Jumps in Clock Rates

By Wm. A. Conrad

THE standard clock system of the U. S. Naval Observatory consists of three sideral Riefler clocks substantially mounted in airtight cases in the constant temperature vault. One of the three is used as the standard clock, the others as auxiliaries. It having been noted, in determining the clock corrections for the time service based on six to eight well-determined clock stars culminating within 10 degrees of the zenith, that there seemed to be sudden jumps in the clock rates of all three clocks, an investigation was started to find a possible explanation. Because of the excellent operation of the heating system, the very constant temperature maintained in the vault, and the tightness of the sealing, of the cases, it could hardly be due to temperature or barometric changes; hence the cause was attributed to imperfect determination of instrumental constants.

By intercomparisons of the clocks on the chronograph at the time of observation for a clock correction, rates for all three clocks are obtained. These rates being based on short intervals of time, from two to six days, will naturally fluctuate in value about a certain mean, the magnitude of the fluctuations depending upon the steadiness of the clocks and the errors of observation. If the observations were perfect and the fluctuations due to imperfect running of the clocks we would rarely find all three clock rates varying the same amount in the same direction. If, on the other hand, the rates of the clocks were steady and the fluctuations in the observed rates due to errors of observation, we would have all the clocks varying the same amount in the same direction. It has long been noticed that the rates of all three clocks usually vary in the same direction at the same time and by almost equal amounts.

In seeking the cause of a very bad jump in all three clocks in February, 1917, it was noticed that a great many jumps were noted "cold wave" or its equivalent and that all cold wave notes indicated jumps. Cold waves are usually due to the approach of a center of high barometric pressure from the west, and with this as a clue the weather map at the time of the observation under question was consulted and showed a very marked low pressure area receding in the east, followed by an abnormally high barometer coming in from the west. In other words the barometric gradient seemed to bevery steep. Might this not indicate that there should be a correction for lateral refraction applied to the observations?

Now let us assume that the correction to the clock is zero, that it has constant zero rate, and that on the first of the month an observation for a clock correction is obtained under weather conditions such that barometer readings over an extended area around the point of observation are sensibly equal. Leaving out of consideration other sources of error the clock correction then obtained would be zero. If now three days later the barometer shows a decided "low" east of the observatory and a decided "high" west, the air strata would have a well marked tilt downward toward the east. Because of the laws of refraction the star posirions would be thrown toward the east and would transit late, so that a clock correction obtained on this night would indicate that the clock was too fast and the clock correction would be a negative, giving a negative rate. If at the time of the next correction the conditions were reversed the correction would be positive and the rate obtained would be positive, indicating fluctuations in the rate which did not actually exist according to our assumption. It is not necessary that the correction be zero, or that the rate be zero or even constant, so long as it follows some easily ascertainable law. The fluctuations due to lateral refraction amount to deviations from the normal rate curve.

The rate curve of a good clock freed from all external influences, such as shocks, barometric changes, temperature changes, is rather simple, marked, however, at times by sharp well-defined changes. For the purposes of this discussion it is assumed that the rate curve is a broken line, being linear between the points of change—that up to a certain point the clock maintains a linear rate and then changes abruptly to a different slope. The point of these breaks is very evident in the clock rate book and a least square solution for a rate equation of the form

$$R = K + x + y\,(T - T_m)$$

has been made. In some few cases the introduction of a second degree term would better satisfy the observations. With this equation computed corrections were obtained and the residuals O—C derived. When the clock rate solutions are completed and the residuals plotted, it is found that the fluctuations in the residuals are practically identical and furthermore, by the use of the daily maps furnished by the Weather Bureau, the fluctuations could be roughly predicted from the hypothesis that they are due to lateral refraction.

The conclusion that lateral refraction enters into all fundamental star place work to a certain extent, both in right ascension and declination, seems plausible. The observer with the transit circle, zenith tube, or prime vertical, who has a whole night's observations to stand out widely from the mean of the entire work for no explainable reason, may clear up some of his difficulty by a look at the weather map.—Read at the Annual Meeting of the American Astronomical Society.

The Origin of the Thermionic Vacuum Tube

Now Used in Radio Communication and the Electrical Arts

By Philip E. Edelman, E.E.

The thermionic vacuum tube, variously known as the Audion, Fleming valve, Wehnelt Cathode Tube, Audiotron, Oscillion, Kenotron, Pliotron, Dynatron, Pliodynatron, Lieben-Reisz Tube, etc., has a very interesting scientific history which has heretofore not been generally known.

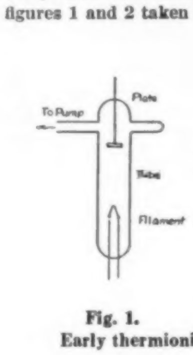
In its present development, this type of vacuum tube is proving and promises to prove of utmost importance in radio-communication and the electrical arts, as a detector, amplifier, beat receiver, oscillator, undamped or sustained wave generator, rectified, and two or more of these functions combined, and in each instance affords means of previously undreamed of possibilities for technical and scientific extensions, some of which, as the amplifying detector, have already been fully demonstrated.

Aside from its well-known uses in radiotelegraph and telephone transmitting and receiving circuits and its importance in long-distance telephony over wire circuits this device is of considerable value in scientific determinations and measurements. Very rapid strides have been made in recent years whereby by suitably connecting such a tube or a number thereof, minute electrical energy may be amplified as much as a thousandfold, alternating current supplies of the order of many kilovolts may be perfectly rectified with an efficiency well above 90 per cent. while low potentials suitable for storage battery charging (Tungar Rectifier) may also be rectified at a commercially feasible efficiency. That this may not be enough, change the circuit slightly and you have a means for converting direct current into alternating current of any desired frequency from ½ cycle per second or less up through the audible range, thence through the inaudible and radio frequency range until a frequency of 20,000,000 or more is reached. The possible tonal effects in the musical range are very pleasing or very piercing according to the slightest movement of the variable condenser controlling knob connected in the circuit. Moreover, a small energy can be supplied to such a tube and be faithfully repeated in far greater amplitude or repeated into another similar tube via such amplification to almost any extent desired, limited only by the construction and characteristics of the tube. The very slightest alteration of the construction of such tubes is found to have remarkable effects, an example being the introduction of the slightest trace of a gas or mercury vapor to greatly decrease the so-called "space charge effect" which means in practice that such introduction of the minutest trace of mercury vapor greatly reduces the voltage drop across the electrodes in the tube. Given this remarkable device with its newly discovered functions such as "negative resistance," etc., it may be assuredly predicted that very important advancements are certain to be carried out in science and the electrical arts by its further and technical applications. For instance, our future railways may be propelled by direct current motors operated on high voltage alternating current supply carried through rectifiers of the thermionic type.

Disregarding the strained claims and counter claims of various patentees, a careful search into the history of this interesting device reveals the truth of the oft-doubted assertion that pure scientific research of apparently no possible immediate value can prove to be of the utmost importance later.

Thus Du Fay, experimenting with static electricity in 1725, little knew how close he was to the now well-understood effect of thermionic conduction when he found and recorded the fact that air in the neighborhood of a red-hot metal becomes a conductor of electricity. More than a century later, Bequerel in 1853 recorded the fact that air was a good conductor at a white heat. A score of years passed thereafter until Guthrie in 1873 recorded (Phil. Mag., IV 46, p. 257) his observations showing that a red hot ball in air could retain a negative but not a positive electrification, while on the other hand, the same ball raised to a white heat could not retain either a positive or a negative charge. Had he but known it, he was already working with the hot cathode electron discharge phenomena. Incidentally he appears to have anticipated the more thorough studies of the Germans, Elster and Geitel, who in 1882 and thereafter thoroughly investigated the phenomena occurring in the vicinity of a heated wire held in a bulb near a plate electrode much after the fashion of the present construction of such devices in their contemporary commercial forms.

Examples of two and three electrode tubes constructed by Elster and Geitel are shown in the accompanying figures 1 and 2 taken from a series of papers in Wiedemann's Annalen (p. 193 No. 6, p. 711 No. 11, p. 588 No. 2, 1883; p. 123, IX, 1884; p. 1, No. 9, 1885; IX, p. 109, 1887). Starting with experiments on conductivity of flames, these two gentlemen extended their investigation through the effects of the contact of gases with glowing bodies and made a careful study of their discovery of the unipolar conduction noticed in the case of heated gases. They used an electrometer as the indicator in their early experiments, using 100 batteries to apply potential to the plate near the platinum wire which was heated in an evacuated vessel by another battery, very much as in modern practice. With apparatus as in figure 1 and trials of different attenuated gases they found that at red heat the filament tended usually to give off positive electricity but that at higher temperatures near the white heat, negative electricity was generally given off. Then evacuating the containing vessel as far as they could they found for the same conditions that the tendency to emit positive electricity previously noticed was greatly lessened while the tendency to emit negative electricity was apparently much stronger than before. They appear to be the first to construct and demonstrate the modern thermionic tube but handled the work from a purely scientific standpoint and largely because of the appeal which the "loss of electricity from a hot body" offered to them. Their results grew logically from their first experiments in which they simply passed gases through a heated tube and projected such heated gases against a plate. The use of a heated filament probably occurred to them simply as a better expedient, and yet on its use hinges the important present-day applications of the phenomena.



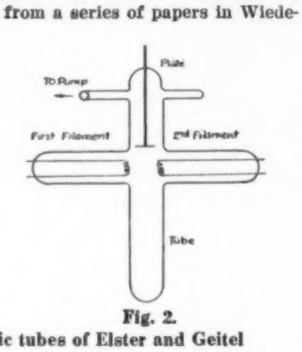


Fig. 1. Fig. 2.
Early thermionic tubes of Elster and Geitel

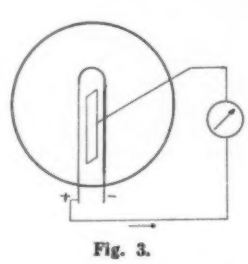
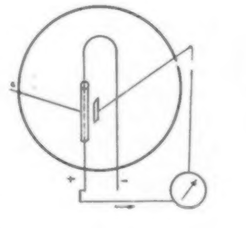


Fig. 3.



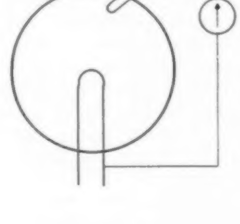


Fig. 4. Fig. 5.
Fleming's experiments on the Edison effect

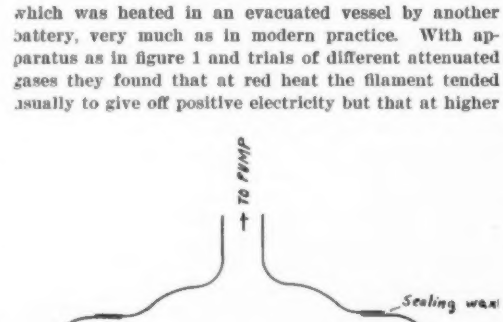


Fig. 6.
Richardson experimental tube

Meantime, our own Edison, busily engaged in work on his incandescent lamp, noticed the same effect in 1884 and described it in *Engineering*. Hence for sometime the phenomena was known as the Edison Effect, a proper designation in view of the fact that the principle work of Elster and Geitel with the hot filament near a plate in a vacuum came at the end of the 1882-1889 period.

Preece, in England, studied the Edison Effect and confirmed the results. (P. 219, Proc. Royal Soc., 1885.)

J. A. Fleming made a further examination of the "Edison Effect in Glow Lamps" and his initial results are set forth in detail beginning on page 52, Vol. 42, *Philosophical Magazine*, 1896. His first work appears to have been directed to ascertain means for avoiding or compensating for the Edison Effect rather than to utilize it for a new purpose, though much later this gentleman applied the phenomena to use in the detection of radiotelegraph signal impulses.

Fleming's original apparatus is illustrated in figures 3, 4 and 5. Figure 3 shows the plate placed adjustably near the looped filament, figure 4 shows an additional plate arranged about the positive half of the filament loop, and figure 5 shows the plate in the form of another filament which could be separately heated, as in the experiments of Elster and Geitel. Fig. 2. Fleming's experiments preceded the latter work of these two German gentlemen but they had already accomplished much before he began.

Fleming found, figure 3, that his galvanometer connected to the plate and the positive half of the filament gave indications as high as 3 or 4 m.a., but that when the negative half of the looped filament was used, only an exceedingly small result was obtained. He used carbon for the filament. He explained that this was due to the fact that there was a vigorous discharge of negative electricity from the negative leg and a very relatively much smaller discharge from the positive half of the filament, so that the potential of the metal plate differed but slightly from that of the negative half of the filament but very considerably in the case of the filament's positive half to plate, being in this latter case nearly as much as the potential difference between the electrodes of the lamp. He recorded that the plate gets a negative charge in a high vacua and that negative current must flow from the negative side of the filament to the plate. He also noticed that the current increased with increase of applied potential, but much faster than by Ohm's law. Another result he reported was that a wire grid gives the same results as a plate of the same total outside area. With the device of figure 5 he found that when both filaments are heated and one used as a plate, it is immaterial which is positive and which negative.

J. J. Thompson (*Phil. Mag.*, XLIV. 1897, p. 203) deflected the charged particles emitted by the hot filament, by means of a magnetic field, and later (*Phil. Mag.*, 48, 547, 1899) showed that when a carbon filament was used in a bulb containing hydrogen at a very low pressure, the negative electricity given off by the filament is in the form of free electrons having a mass of about 1/1800th the mass of a hydrogen atom and according to his explanation, comprising in fact genuine atoms of electricity. Pringsheim (Weid. Annal., LV, p. 507, 1895) repeated some of the early experiments quantitatively and recorded that below saturation, the current increased about as the square of the applied voltage.

E. Bose was able to secure similar effects by using a Nernst filament near a metal electrode 10 centimeters away therefrom in a vacuum, and obtained a current of 10^{-4} amp. (Annalen der Physik, p. 177, 1902).

J. A. McClelland tried various materials for the

filament and varied the nature of the gas thereabout. It was found that platinum at high temperature produced only a negative charge in all surrounding gases. (Proc. Camb. Phil. Soc., X, p. 241, 1900; XI, p. 296, 1902).

W. Wien reported in the Annalen der Physik, Vol. 8, p. 244, 1902, that a hot wire in a very good vacuum can discharge electricity to a distant small electrode if it is charged to a high potential and for his apparatus he found that 800 volts was required for negative electricity and 3,000 volts for positive.

Earlier, Wilson (Phil. Trans., 1899, p. 499) had noticed the difference between the velocity of the negative ions and the positive ions, and said that at 2,000 degrees C the velocity of the negative ion was 17 times greater than that of the positive one. J. J. Thompson also made some further experiments and (*Phil. Mag.*, 1902, p. 98) related how hot metals emit positive as well as negative electricity, observing however that at a very high temperature more negative than positive are emitted and vice versa at relatively low temperatures. By using copper and silver wires, for example, at 200 degrees C he was able to detect positive emission from these wires.

Important quantitative determinations were recorded by O. W. Richardson (Camb. Phil. Proc., Vol. 11, p. 286, 1902), who again observed that air in the neighborhood of hot metal discharges electricity and proceeded to vary the constants. At low pressures according to the gas used, he observed that the charge may be either positive or negative. His most important results, however, were quantity measurements on a hot platinum wire surrounded by a metal cylinder. By plotting curves and noting the conditions he formulated the governing equations for the current. According to his results, for example, a carbon filament could emit as much as one ampere per square centimeter of surface, while for platinum at the melting point this would be one-tenth of an ampere per square centimeter. He determined temperatures by measuring the resistance of the heated wire. By this time it had been established that saturation current existed for both the condition of the temperature of the filament and the potential applied, each being a limitation which governs the limits of the other. Ohm's law does not hold for such a conductor as the hot filament to plate circuit in an evacuated vessel. For platinum in air at low pressures, Richardson found that positive ionization was produced. (*Phil. Mag.*, p. 80, 1903, Vol. 6.) Figure 6 shows his experimental arrangement with a pair of filaments in a vessel which was connected to a pump.

Richardson's work was based on the electron theory. Like Riecke and Drude he assumed that electrons exist in a metal, that they are in motion like the molecules of a gas, and that they are free to move upon the application of an electric force. He considered that these electrons were ordinarily held at the surface of the metal by electric force and so generally kept within the metal, much as surface tensions holds liquid molecules. Accordingly for an electron to escape its motion must increase, that is, the temperature must be raised. The analogy follows closely to vapor pressure phenomena and he said that at a given temperature the incandescent body emits a definite number of electrons independently on the electric field thereabout. Thus when the positively charged plate is placed near to the hot filament, since unlike charges attract each other, the electrons are drawn away from the filament and absorbed by the plate, and it is this motion from the one to the other that constitutes an electric current, the filament forming the cathode and the plate the anode. In the absence of an electric field about the filament or if a negatively charged body or grid be placed near to it, the electrons which are emitted are simply driven back and re-absorbed into the filament, so that no current flows. The electron emission increases with increase of temperature until saturation is reached, that is, increase of temperature will permit no more electrons to escape. The temperature then controls the electron emission. The current or flow of electrons, however, is governed solely by the potential existing between the filament and the body to which the electrons move. This current also becomes saturated as the potential is reached at which all the electrons that can be moved are moved to the anode as rapidly as the temperature permits.

H. A. Wilson (Phil. Trans, 202, p. 243, 1903) repeated some of Richardson's experiments and noted the effect of treatment of the filament. He found that by first heating the platinum filament in oxygen or by boiling it in nitric acid, the emission at high temperature was enormously decreased to 1/250,000th of its former value. As soon as a little hydrogen was admitted to this treated filament, however, he found that the emission was again restored to its former value. Figure 7 shows the arrangement of the tube used in these determinations.

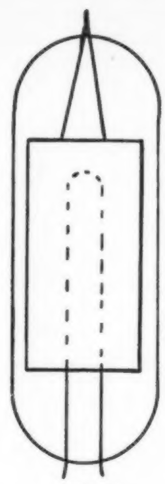


Fig. 7.

A. Wehnelt found that the emission from heated platinum could be greatly increased by a coating of oxides of calcium, barium or strontium. (Ann. Phys., 14, p. 425, 1904, and *Phil. Mag.*, 10, p. 80, 1905.) Figure 8 shows the form of tube he used, with a cylindrical plate around the coated filament. Figure 9 shows the oxide coating on the filament. This coating is best applied in several thin layers, allowing each to dry before the next dipping. Wehnelt's tube is naturally best suited where the highest attainable vacuum is not required. He also showed the use of a magnet coil around the tube to direct the electron stream. G. Owen (*Phil. Mag.*, VIII, p. 230, 1904) repeated and confirmed Bose's experiment with the Nernst filament.

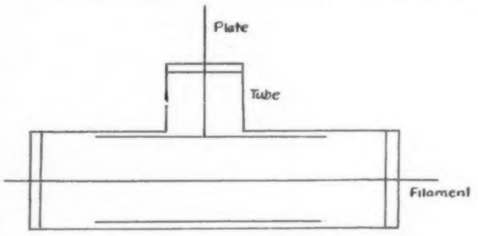


Fig. 8. Wehnelt ozide filament tube

Fig. 9. Wehnelt's oxide filament.

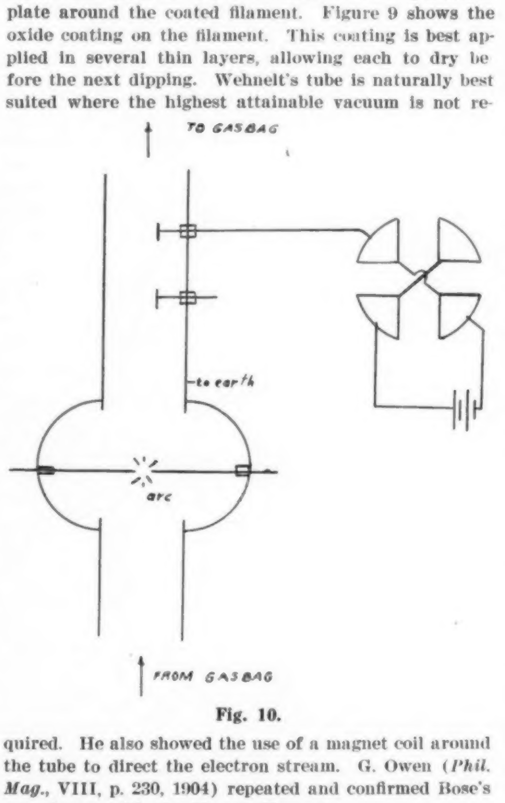


Fig. 10.

At the International Electrical Congress in St. Louis in 1904 P. Lewis said that a gentleman named Kinnersley of Philadelphia had more than a century ago observed that steam from electrified water is uncharged, and J. Townsend gave a resumé of the theory of ionization by collision. In air, according to Townsend, a negative ion can produce 700 ions by collision with the gas molecules in a distance of ten meters, while for similar conditions a positive ion can produce but six (for air). For hydrogen the ratio is less (333 to 17). In the present day audions, tungars, etc., tubes this ionization by collision has a marked and important effect in making the devices useful on low operating voltages. The phenomena of ionization by collision alters the operating characteristic very much from the characteristic for a similar tube in a high vacuum. In practice such tubes are distinguishable by the characteristic gas glow, usually a bluish glow.

F. Deininger investigated the ionization from carbon and various metals, alone and in the presence of lime, and confirmed Richardson's formula for the ionization current as a function of the absolute temperature of the filament. (Ber. Deutsch Phys. Ges., 1907, IX, p. 674.)

Soddy endeavored to show that thermionic currents depended upon the presence of a gas and found that Wehnelt's tube became inoperative when the large currents previously obtainable were stopped by absorbing the gases present in the tube with some metallic calcium (Phys. Zeit., 9, p. 8, 1908), which was partly confirmed by Fredenhagen (Verhandlung Deut. Phys. Ges., 14, p. 384, 1912), though disputed by Lilienfeld (Physik Zeitschr., 9, p. 193, 1908). Other workers, including Pring and Parker, found similar results. (*Phil. Mag.*, 23, p. 192, 1912; Proc. Royal Soc., A 89, p. 344, 1913.) Wehnelt contradicted Soddy. (Phys. Zeits., IX, p. 134, 1908.)

McClelland made some further experiments by passing gases through an electric arc and observing the resulting conductivity thereof, as in figure 10, with an electrometer. (Proc. Camb. Phil. Soc., Vol. 10, p. 241, 1912.)

I. Langmuir studied the effect of space charge and residual gases on thermionic currents in high vacua. (Vol. 2, No. 6, 1913, *Phys. Review.*) His work was with very highly evacuated tubes such as had not previously been possible; less than .0001 millimeter. During exhaustion his tube was either heated to 360 degrees C or immersed in liquid air for at least an hour. Another development contributed by this worker is the use of the refractory metals tungsten, molybdenum, etc., and other refinements of construction. (Proc. I. R. E., Vol. 3, No. 3, 1915, p. 261.)

Sheard and Woodbury repeated some of the early experiments concerning the effect of temperature and surface conditions affected the positive ionization from heated platinum. (*Phys. Rev.*, No. 4, Voy. 2, 1913, p. 289.)

Forter made some experiments showing the operating characteristics of Wehnelt's tube. (Ann. der Physik, 40, p. 566, 1913.)

Coolidge utilized the hot cathode discharge in constructing his tube for the production of powerful X-rays. (*Phys. Rev.*, II, 1913, p. 409.)

S. Dushman developed the Fleming valve for use at high pressures. (General Electric Review, March, 1915.)

G. S. Meikle developed a smaller argon gas-filled tube for low voltage rectification. (General Electric Rev., April, 1916.) One development indicated by this worker is that the initial heating of the filament may be dispensed with after the electron and ionized gas stream is once started as the bombardment of the particles maintains the cathode at an electron emitting temperature.

As regards practical radiocommunication applications De Forest early described his audion (Trans. A. I. E. E., 1906), but issued most of his results in the form of patents, a subject not at present under consideration. His detector and amplifier is described in Vol. 2, No. 1, Proc. I. R. E., 1914. He determined and demonstrated the value of the grid or third control electrode in such tubes as are under consideration and did much to make their construction and use practical.

As regards current developments, they are mostly concerned with improvements, refinements, increased capacity and efficiency, and more particularly with arrangements of circuits such as are described in numerous recent and pending patents which are not here under consideration.

The subject of circuits for such tubes is in itself an extensive and fascinating field which cannot be more than mentioned here. A change of circuit connections very materially affects the operation of the tube, and indeed its very purpose, as for example, when it is connected according to the method of Dr. Hull (W. A., July, 1917, p. 750) for electron production by secondary emission. (As in the Dynatron and Plio-dynatron.) Among the circuits, that known as the Armstrong is of interest. (Proc. I. R. E., 1915, Vol. 3, No. 3.) Though similar forms are shown by earlier patentees. The stunts accomplished with circuits including tubes of this type vary from the transcontinental radiotelephone tests of 1915 to the measure-

ment of corona phenomena, and as regards possible applications in the future there is, as yet, no end in sight.

Thus limiting our considerations to the purely scientific developments we see how, if at times independently, the work of Du Fay and his successors, interconnects until we have the present-day developments which are immediately due to inventors or technical appliers of the recorded scientific principles, many of whom have not been herein mentioned. It is a narrative of scientific progress, which if continued, as it promises to be, will become increasingly important in the future, not only in the electrical arts but to science itself.

The Experiences of An Iron Atom—I*

The Cycle of Its Life History

By Charles R. Sturdevant[1]

I AM one of the smallest things in the universe, and one of the very oldest. The earth itself is younger than I, for I was born and cradled in the seething billows of the sun.

From the time of my nativity, infinite aeons ago, to the present, my career has been filled with thrilling incidents. I have traveled through distances and have survived experiences too great even for your imagination to compass. Within the tiny sphere of my being lie hidden the records of the ultimate structure of all matter and within the minute bodies of such as I are potential forces that would wreck the earth if all were to be liberated at once. In all this world, Mr. Man, you have no servitor so universally useful as I and my kind. Without me you would have no railways, no steam engines, no telegraph or telephone systems. You would still be in the middle ages of civilization.

What I now am, how and whence I came into being, my associates and finally, my life of captivity by man—all go to make up a dramatic story which I hope you will find of unusual interest.

In relating this story, I shall occasionally find it necessary to use numbers of such an order of magnitude as to tax the powers of your imagination. This is because I belong to an order of being strange to you, and live in a very different atmosphere than that to which you are accustomed; so radically different in fact, that you may never hope to experience me directly through any of your five senses, even with the aid of the most powerful or sensitive instruments which you have devised to increase the range and acuteness of those senses. Some of my adventures have been so strange and thrilling that you may doubt my statements, but I cannot tell an untruth for I am part of the reality and verity of the universe.

IN WHICH I INTRODUCE MYSELF.

If you had eyes that were very large and very sensitive, fingers that were absurdly small and delicate, and instruments microscopic in size; and if with these you were to divide a very short piece of small wire made of *pure iron* and were to keep on dividing and subdividing and sub-dividing each small piece, you would in time reach a limit of division. The result would ultimately be a piece so small as to make further subdivision impossible. Such a piece of iron would be called an *atom* of iron, and it would exactly duplicate me in all respects. There are countless millions of atoms in this earth such as I, all alike.

The smallest object visible to your eye at a distance of 10 inches measures 1/250 of an inch. It would require about half a million of such beings as I laid side by side to span such an object. The most powerful microscope would need to have its resolving power multiplied several hundred fold before you could see me. Yet I am very real. I vibrate ceaselessly and move about with such exceedingly great activity that in all probability my exact diameter will never be ascertained.

I belong to a group or class of about 92 of so-called chemical "elements." We represent as many different kinds of substances. In this group are found such elements as gold and silver, oxygen and hydrogen, tin and sulphur, all differing in their physical properties or attributes. We constitute so many different kinds of unit building bricks out of the permutations and combinations of which all things in the universe are made. All atoms are alike in being indestructible, indivisible, uncreatable, eternal—so far as you are concerned. "All the King's horses and all the King's men" could never create or destroy or divide any one of us.

"Everything in God's universe of world and stars is made of atoms, in quantities x, y or z respectively. Men, mice and mountains, the red belt of Jupiter and the rings of Saturn, one and all are but ever-shifting, ever-varying swarms of atoms. Many kinds of atoms, like myself, bulk large in the world's mass, others lie furtively in the hidden places of the earth and are obtained and isolated only with infinite pains and cost. Thus iridium is four times, thorium nine times, cassium 15 times and very impure radium thousands of times rarer and more costly than gold, while others are so rare that they cannot be bought at all."

I resemble the other kinds of atoms in certain other respects also. Instead of being solid, inert substances, as you may have supposed, we are all complex in structure and intensely active, even though minute in size. There are within my spherical surface perhaps 100,000 or more extremely minute particles revolving with great speed about my positive nucleus in regular miniature and planetary fashion. While they move with different velocities, they have the tremendous average velocity of 90,000 miles per second, or half the speed of light. They are so extremely small and active that I have never yet been able to determine their exact number or character.

These particles are called "electrons" and they have every indication of being negative charges of electricity. They constitute minute centers of energy. All electrons of different atoms are identical in all respects, and they appear to be minute vortex rings of ether, though this is hypothetical. The electrons are in fact the ultimate structural units out of which all atoms and hence all substances are constructed. Other atoms differ from me only in having a different number and different arrangement of these unit electrons. All atoms are structural modifications of these entities.

Then again, my being as a whole is extremely active and mobile. I have several motions, varying as I am brought into different environments—such as transitory, reciprocal, oscillatory and what is most effective, vibratory. My motions, or those of the molecule of which I may be a constituent part, are always imparted to the all-pervading and extremely tenuous ether in which everything is submerged.

I set the ether in sympathetic vibratory motion and it transmits my motion to distant bodies. Upon these are produced effects of heat or light or chemical action. The ether receives, transmits and imparts our energies. This can be illustrated by the vibratory motion of the atoms in the sum which are transmitted by the ether to the earth, a distance of 93,000,000 miles. When these transverse ether waves strike the earth they give off light and heat, and when they come in contact with certain substances, such as molecules of a living green leaf or a sensitive camera plate, they shake the molecules to pieces, causing chemical changes to take place. In fact these ether waves liberate about 150 foot pounds of the sun's energy per second on each square foot of the earth's surface.

When I, in bulk (*i. e.*, as a piece of iron), am heated in a dark place until I begin to emit light rays which are just visible to you as a dull red color, I am at such a time vibrating at the tremendous rate of 392 million million times per second. This rate of vibration rapidly increases as I become hotter, or as the light grows brighter.

The motions of my constituent electrons are likewise imparted to the ether and produce either electrical, magnetic or radio-active effects on other bodies, the manifestation in each case depending on the character of the motions. I have therefore the power of manifesting my presence to you in these several ways, even though I produce no direct effect on your senses.

Under favorable conditions, the converse of these actions is true; that is, if I am placed in an environment where light or heat or electrical or magnetic energy from external sources is being dissipated, either I as a whole or my electrons will be affected and our motions will be accelerated or retarded.

You see from the foregoing that I am virtually a minute reservoir of intensely concentrated energy, and it is a special exalted form or node of energy called "intrinsic." If you, Mr. Man, can ever find an agency through which I may be destroyed or broken down into simpler parts (*i. e.*, if you ever can by some means dissipate a considerable portion of my electrons), you will have tapped an unlimited source of energy with which you could revolutionize the physical world.

If one gram (15.4 grains) of radium could be instantly and completely broken down or disassociated into its electrons, it would (according to one of your scientists) unlock sufficient power to throw the whole of the British fleet from the Channel to the top of Mt. Blanc.

This excessively active state was imparted to my being at the time of my creation and I have never lost it and probably never shall until the end of all things. This perpetual and strenuous activity at times makes me very tired, and I am ever alert for an opportunity to impart some of my activity to other atoms with which I am thrown into intimate contact. But I can do this only when the others contain less energy than I, as for instance when they are at a lower temperature than I am—*i. e.*, if their motions are slower than mine. If they should contain more energy than I, then my rate of motion would be increased and I would be worse off than before.

I have never been weighed. Even your most delicate weighing instruments are altogether too gross for such as I. I do know, however, that I weigh 56 times as much as a hydrogen atom, which is known to be the lightest of all and which is said to have unit atomic weight.

I am naturally a very social creature. In all my career on the earth, I have seldom been alone or by myself, and have always been somewhat particular with whom I associated. For instance, I have never been able to get along with lead. I am especially fond of the element oxygen with which I combine in three different proportions, making as many different so-called iron oxides. I also readily unite with silicon, carbon, phosphorus, sulphur, manganese and a number of others. These close combinations of wedded atoms constitute the so-called molecules—the smallest possible divisions or particles of compound substances.

These unions of myself with different kinds of atoms into molecules are, within certain limits, under your control, Mr. Man.

Each particular combination or chemical compound has a set of physical properties all its own, some of which differ profoundly from mine as iron. Since there are no such things in chemistry as fractional parts of atoms, I am invariably combined with a certain definite number of whole atoms, if with any.

When I do unite with other atoms, the settings must be favorable and the ceremony is the occasion for an exchange among ourselves of one or more electrons, and of a corresponding transformation of energy. Among other things all our complex motions are altered and heat is evolved. And in order to separate me from any molecule of which I am a constituent part, heat must be supplied from without in a quantity equal to that given off by the initial formation of the same molecule. At the same time other atoms must be brought into intimate contact with us which have a stronger affinity for me or my mates than we possess for each other.

I and the other atoms constituting any molecule are bound together by electrical forces, generally called chemical affinity. Our atoms cannot be broken apart except as these binding forces are overcome by the application of some form of energy from without or by the presentation under favorable circumstances of other and more attractive atoms when new groups or molecules will be formed. These molecular changes are going on continually about you, though you are quite unable to perceive them.

The growth and sustenance of animal and vegetable life as well as all chemical changes in inorganic materials is conditional on such activities in our atomic or molecular world. We are in a state of perpetual, unremitting quiver, and whenever any one of us can give up some of our pent-up energy by forming new combinations, or breaking down old ones, we do so.

Speaking of animal life, I wonder if you know that I constitute a most essential part of the building material required by all mammals to sustain life. Among other things, I perform a very important func-

*A paper read before the Cleveland Engineering Society, and published in its journal.

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tion in every red blood corpuscle, of which there are millions and millions in your own circulatory system. My presence here makes it possible for the blood to carry oxygen from the lungs to the living cells, where it unites with carbon giving off bodily heat and certain vital forces.

There are only three things that you can accomplish with me and my kind. You can move me about from place to place, you can within limits determine whom I am to have for my mates, and I am sorry to say you have been able to put me to work. The whole iron and steel business which you have developed, with all its wonderful train of consequences, constructive and destructive, is based upon your ability to do these three things with me.

As we iron atoms serve innumerable uses to man wherever he makes his abode on earth, so Providence distributed us to all communities. Of all metals we are by far the most useful to man because of our many useful properties—and we are the most abundant and most accessible. Of all the material in the earth's crust, 4.44 per cent by weight is iron. There are but three elements which exist in greater abundance than I, $O = 47.17$ per cent, $Si = 28$ per cent, and Al 7.84 per cent. Gold, silver, copper, platinum and aluminum—all are wanting in the hardness and rigidity which suit the iron family to many of its most important adaptations, not one of these metals could be used for track rails or for building or engineering purposes. Neither would they furnish a tool having the edge and temper of fine cutlery. Save nickel, iron is the most tenacious of all useful metals, and it can readily be welded, or forged, or molded into any desired shape. When compounded with certain other elements and treated in certain fashion, it will respond to almost any requirements as to strength, toughness, hardness or resilience. Without me there could be no electrical instrument or machine, for I possess more wonderful magnetic powers than any other metal. I am the undisputed king of metals.

II

MY ORIGIN AND HISTORY

This story would be very incomplete were I not to give you a brief history of my wonderful past. As I look back over my eventful career it seems almost incredible that such wonderful adventures should have fallen to my lot. In the great volume recording the history of the universe will no doubt be found a chapter giving a full and detailed history of my origin and of my activities. But that volume has not as yet been revealed to man, and until such time as it is no other account can ever hope to be complete or perhaps wholly accurate. But, at any rate, such a history would be altogether too long for the purpose we have in view, so this account will be very brief, and, I hope, of interest to you.

My origin antedates the earth's nativity, for I was evolved in the sun ages before any of the planetary births, billions of years ago. At the time of my evolution the sun—that relic of the primordial fire-mist and the historian of a mighty past—was not the same sun that shines upon the earth today. It was much larger and hotter than it is now, and it revolved on its axis much more rapidly than it does at present. It was a great globe of incandescent gas, subject to powerful eruptive actions, and it contained an enormous concentration of energy arising from its molecular activity and its high gravitative compression.

In the earliest stages of the sun's history only a few of the lighter elements existed, such as hydrogen, helium and asterium. As the sun dissipated heat and lowered in temperature, other elements came into being by the association or grouping of definite systems of electrons. I was one of the first metals to appear. Associated with me during these early stages of evolutionary atomic development were silica, calcium, manganese and a few others. Whether the electrons out of which all of us were made had existed in our sun or in other suns from eternity of the past—or whether they themselves had been evolved in the sun before my time—I am unable to say. Neither have I ever been able to ascertain the exact nature of their ultimate structure. An account of their history and nature would supply a knowledge of the very foundation of all science; it would constitute a key which would solve the riddle of the universe.

Thus, through immeasurable periods of time, amid inconceivable scenes of fury and excessive activities of kinetic development, I was evolved in the seething fire mists of the sun. These occult energies of atomic association endowed me with all the wonderful attributes which I still possess and which have actuated me during all my prolonged history. The hand that fashioned my being and first gave me activity also gave me perpetual youth and vigor.

After seeming eternities of existence in the sun, and long after I thought I had become settled in life, there came a period when a wandering star or other celestial body made a distant approach to our sun and caused a great disturbance therein. Its approach was accompanied by a differential gravitational pull which drew forth on the sun's surface immense tidal bulges or cones of sun material on the opposite sides of the sun.

At the same time that the cones were drawn out on the line joining the sun and star, a bolt of inward pressure was brought into play at right angles to them. The joint effect of the protrusion of the cones and the compression at right angles to them was a concentration of the sun's eruptive tendencies into the cones. At the same time the eruptive function was powerfully stimulated. As a result the sun shot out great gas bolts from the quasi-volcanic cones whose mass was much greater and whose velocity was much higher than that of the eruptive prominences which are now shot forth at intervals in a more sporadic way. The sun shot forth gas bolts to the amount of 1/745 of its mass, which was sufficient to form the members of the whole planetary family, including the earth. These gas bolts were given a transverse momentum by the attraction of the passing star. Thus the planets into which they were later collected received their high endowments of momentum.

One of the bolts of fiery matter (in which I was included) which was shot out from the sun formed into "a nebulous knot, which served as a nucleus or crater upon which fell much scattered nebulous matter during later periods. The central portion of the knot, constituting only a minor fraction of the adult earth, was in a dormantly inter-collisional state, while the outer portion was almost inevitably in a dominantly orbital state, the latter circling about the former. The central inter-collisional portion rapidly collapsed into a dense spheroid so far as composed of rock substances. The portion that revolved about this, after the manner of minute satellites, was collected only as the occasional collision of the small satellites drove them from their orbits into the earth nucleus, or else they were driven in by falling bodies from without."—(T. C. Chamberlaind.)

In some such manner the earth was born and endowed with its motions and with its energy. It was under such circumstances that I left the sun and became an essential, though tiny, part of the earth. Of my existence in the earth during its adolescence—when it was passing through fiery stages of youth, during those ages when oceans and continents were being evolved, and on down during those later geologic ages which witnessed the evolution of all vegetable and animal life—I shall not attempt here, for lack of time, to give an account, though I vividly recall my life in those days so filled with stirring scenes, wild excitement and thrilling adventures, that in comparison my recent experiences have been placid indeed.

During all the earlier ages of the earth's development I was shifted about from place to place by various agencies, sometimes being deep down in the abyss of the earth, and sometimes on the surface or dissolved in its waters.

The static pressure near the earth's center is now about 22,500 tons per square inch, and the center is in a highly-heated and rigid and elastic state. You cannot wonder then that I was most happy to find myself one of the great mass of lucky atoms to be finally thrown to the earth's surface, where I would escape such an unpleasant and eternal imprisonment.

As a final result of all the mighty world-making activities we iron atoms have been pretty thoroughly scattered about over the earth, and we are often found in great beds both at the surface and at great depths. It will not be wondered at that we are never found in the pure state (except as meteorites which have fallen to the earth), but that we are always combined with other elements, especially with oxygen. Iron atoms abound universally as constituents in the rocks and minerals of all geologic ages. We are dissolved or held suspended in nearly all waters, and we abound even in the bogs formed during your time.

Our presence is often indicated by black, brown, red or yellowish color, though many times showing no color at all. Red soil, so prevalent in some regions—red sandstone, red shale, red brick, like the red rust on the track rail—all indicate our presence as a red oxide of iron. Iron imparts the beautiful tints and shades to many a precious stone or jewel which you prize so highly. The yellow precipitate on the bottom of the stream is the same, plus water in combination—that is, when I am united with oxygen and with water in crystal form my color is yellow like ochre.

To be more specific as to my own career, at a certain time in an early stage of the earth's development, when it was surrounded by an envelope of dense and highly heated poisonous gases, a great mass of molten rock material, containing about 6 per cent of iron oxide, by a mighty outbreak of the earth's imprisoned forces, was forced to the surface through other masses already formed, and in time it also cooled and solidified into a thin crust of igneous rock. I was included in this mass as a molecule of ferrous oxide (FeO). During subsequent upheavals and torrential rains this rock suffered decay. Most of the iron which it contained was leached out of the rock and went into solution, while the remainder was held in suspension. I was carried by this water over some highly heated sedimentary rocks, which gave to the water some of their silicates and carbonates, and other mineral substances. This iron-bearing and mineral-charged water finally came to rest in a distant large open rock basin, and in time—by evaporation and chemical reactions—all the mineral substances were precipitated to the bottom of this basin.

Some of the iron atoms were present as ferrous oxides, some as ferrous silicates, and some as carbonates. In course of time there was concentrated here a large bed of iron ore, mixed with and covered by sediment of various kinds.

During the pre-Cambrian age especially—and to a lesser extent during later ages—percolating waters passing down from above produced changes in the chemical and physical character of the original bed. The vegetable matter decayed and disappeared; a period of high temperature drove out all water of crystallization from the limonites, the original carbonates and siderites were decomposed and their iron was changed to the ferric state (Fe_2O_3). While all these changes were taking place our bed was slowly being covered with a thick layer of earthy material, brought down by freshets in the stream that emptied into this basin.

I do not wish to give you the impression that all iron ore beds were formed in this particular manner. I am only relating in a general way what happened to me and my immediate neighbors. I understand that other large deposits have been produced by other agencies than water. In some places heat was the selective agency; in others chemical or electro-chemical action caused the iron ores to segregate into veins or lobes. However, probably nine-tenths of all the ore beds were formed by the action of water which carried it off mechanically or in solution, and re-deposited it in beds.

I remained in this ore bed as part of a ferric oxide molecule (Fe_2O_3) quite near the earth's surface too, for a very, very long period of time. Trees and ferns grew above me, lived for hundreds of years and then disappeared; seasons came and went for hundreds of thousands of years until I despaired of ever seeing the sunlight again. I had a weary, weary wait in this damp, dark grave, but I lived on.

Ultimately our ore bed was discovered by man, and then began a series of stirring and interesting events for me, which will make a chapter in itself.

III

IN WHICH I AM DISCOVERED BY MAN

For a long time I had been hearing unusual sounds and feeling the jarring of heavy machinery above me, and I knew that something very unusual was happening. The disturbances approached nearer and nearer until suddenly, with no special warning, I found myself being lifted up in a large steel bucket along with all my iron ore neighbors.

This took place in the afternoon of a bright, clear day. At first the sunshine blinded me, for it had been an immensely long time since I had last seen the sun. When I regained my sight sufficiently to look about, I noticed that we were being lifted and moved about by a large steam shovel. I could see but one man operating this machine, and I noticed that he could apparently make it do anything he wished. This was the first man I had ever seen, for man had not yet come into existence when I last saw the light of day. But I was destined to see much more of him and to learn of those truly wonderful intellectual and rational powers with which he alone of all animal life has been endowed. I soon learned that through the possession of these powers, man is given the ability to control and utilize these natural forces and forms of energy and to move and shape materials as he may choose in order the better to serve his ends.

There were a number of steam shovels working near by, and I saw that they together had dug an

immense hole in the earth, which was very deep and which covered many acres. It was apparently in the midst of a forest, for many trees were standing about the edge of the hole.

Well, I was quickly dumped into an ore car standing near the shovel and was soon covered up. For many days thereafter, just how many I do not know, I was kept constantly on the move. I occasionally had an opportunity to look about me, but much of the time I was buried deep in ore. That which I am about to relate concerning my adventures was learned partially from my fellows and partially from conversation between men which I could not help overhearing.

Our car was one of a long train of ore cars, each carrying 50 tons. I was therefore but one of many millions of iron atoms which our car contained. After all the cars had been filled, the train was hauled many miles to an ore dock on the shore of a big body of water. Here the train mounted a high trestle, which was built over shipping wharves, and the ore was dumped into bins holding from five to eight carloads. I remained in one of these large bins a few days, and was then forced down through a chute into the hold of a monster ore vessel. Our vessel was loaded in about 25 minutes with 12,000 tons of ore. Last year (1916) 60,000,000 tons of ore were shipped from this region (Lake Superior) alone.

After several days en route our boat was finally tied to a dock located on a river front near the plant of a large blast furnace. It required less than two hours to unload our boat. This was accomplished by using huge ore traveling cranes and ore bridges. And here I became one of the billions of iron atoms forming a great ore pile, while all around were other large bodies of material brought here by train and boat. A vast aggregation collected by man to serve his needs.

In what follows I shall purposely omit all those mechanical details of structures and processes which you can see with your physical eyes, and will confine myself to a description of those actions and details which would be impossible for you to observe. In other words, I will act as an instrument to magnify the powers of your mind's eye just as the microscope reveals new worlds to your physical eye.

IV.

IN WHICH I AM CONVERTED INTO PIG IRON.

I remained in this artificial pile of ore for several months. Finally there came a day when I was loaded into a small car along with quantities of one or two other grades of ore, and was drawn to the bottom of an inclined steel track. Here we were first weighed, then dumped into another odd-looking car underneath ours. This container, called a skip car, was hauled by a cable to the top of an inclined track and automatically dumped into a small hopper located in the upper portion of a 90-foot stack of varying diameter. This stack was the central feature of the blast furnace plant, and I noticed that surrounding and adjacent to it was a forest of pipes and small stacks.

The bottom portion of our hopper, shaped like a bell, was soon lowered, and our skip load of ore slid down into a much larger hopper, the bottom of which was already covered by coke, which rested on another and larger bell. A skip load of limestone was soon poured in on top of us—then the large bell supporting about half a "charge" was lowered and we slid down into the upper end of a shaft on top of a lot of stock previously introduced. A complete "charge" or "round" of material here consisted, I was told, of ore, coke and limestone in the proportion of two parts by weight of ore to one of coke and one-half of limestone. This material—a total of 2,000 tons per day—was handled in such a manner that it was quite evenly arranged in layers in the shaft.

Hot, poisonous gases came rushing up through the stock with a deafening roar, and I did not know what to expect next. As charge after charge was piled in above us we kept descending further and further down the shaft into zones of ever-increasing temperature.

Let me explain here more fully the exact condition I was in with respect to my neighbors and companions, so that you may better understand what is to follow. I was a minute part of a small chunk of ore about the size of an egg. If you were to take this in your hand and examine it closely, you would find it to be made up of a great number of small, loosely adhering grains or crystals, some of which are sand, some of stone—and you will find also a little clay. By far the greater number, however, are minute grains of hematite ore, crystalline in appearance. This chunk of ore might be compared to a mixture of red iron rust and earth materials which could be crushed in the hand like mold. Since I was a constituent part of one of these small grains of ore, let me tell you more in detail of its particular structure, because this is outside the range of your powers of observation.

First, as to its chemical nature. Our crystalline grain, though so small that you could scarcely handle it with your fingers, contains many hundreds of thousands of molecules, a great majority of which are alike and contain five atoms—two of iron and three of oxygen, Fe_2O_3. I am a part of one of those molecules, and, as I have already explained, our molecule is held securely together by mutually attractive electric forces. Of the remaining number of molecules constituting the grain, many are made of iron atoms combined with definite numbers of phosphorus, sulphur, manganese of silicon atoms in various combinations. Some molecules contain no iron at all, and a very few contain atoms of other metals, such as copper, nickel and titanium.

These molecules had combined in a compact though irregular manner, and were held together by cohesive forces. They do not constitute a perfect crystal because of the many kinds of dissimilar molecules present. So you see our little grain of ore (little to you, but not to us) is quite complex in both its chemical and physical structure. You must not think that all the ore in the piles was in this condition, for it was not. Some of it looked like solid pieces of red or dark stone, while others were lamellar or stratified in structure, and some of it was in a finely pulverized state. But all of it had much the same chemical structure, and contained about 52 per cent metallic iron.

As soon as the temperature of our piece of ore had been raised to above 212 degrees Fahr., the contained moisture was vaporized and driven off. This action, together with the ever-increasing heat, caused the chunk to partially disintegrate, thus permitting the hot ore to be permeated by the penetrating gases. When in descending the shaft we had attained a temperature of about 400 degrees Fahr., I noticed a weakening of the binding forces holding the molecules of our grain together, and shortly after this a curious adventure befell us.

In passing through the range of temperature from 400 degrees to about 800 degrees Fahr. all of the iron oxide molecules in our vicinity were forcibly attacked from all sides by a multitude of carbon monoxide molecules, which were determined to capture and carry away with them all the oxygen atoms from our midst. In spite of our combined resistance, our crystalline grain was completely broken down by the united effects of the ever-increasing temperature and this horde of strange and violent molecules. As a result we lost nearly all—but not quite all—of our oxygen atoms. We lost and the carbon gained oxygen.

When I first realized the loss of my oxygen companions, with whom I had been so closely associated for ages and ages, I felt much grieved and very lonely. But as there is no great loss without some small gain, so here, the loss resulted in a little rest, for I soon discovered that my vibratory motion had been very slightly reduced. In other words, I had been afforded an opportunity to impart a little heat as a final result of all the changes that had taken place.

As fast as our iron molecules lost their oxygen atoms we were left in the condition of a porous mass that looked like a small, black sponge. At 700 degrees Fahr. this spongy mass began to take on a deposit of pure, fine carbon dust, by which it shortly became entirely covered. Later on, just before we reached the melting temperature, the solid carbon attracted to itself and united with the last oxygen atoms in our midst.

Those active gaseous molecules that brought about the foregoing changes were made up of two atoms, one each of carbon and oxygen (CO), known as "carbon monoxide" gas. This molecule was unstable and unsatisfied. The carbon was craving another oxygen atom. It felt as you would feel were you thrust out into a public street with but one shoe. You could get along with one, but you would be mighty uncomfortable and unhappy until you found another shoe, and you would be willing to pay more for the second than for the first.

The carbon atom gave off 70 per cent more heat when it united with the second oxygen atom, making CO_2 (carbon dioxide), than when it united with the first, making carbon monoxide. When these molecules rushed up into our midst, we afforded them their first opportunity of satisfying their strong desire for more oxygen, and hence the reason we lost our oxygen to them. The new gas (CO_2) thus formed joined the main current of gases, rushed up the stack and passed out at the top through the downcomer.

After I had moved down the shaft to a depth of about 20 feet I heard neighboring limestone molecules complain that they were being pulled apart or "dissociated," and sure enough when the temperature reached 1100 degrees Fahr., the heat alone began to separate these molecules into lime or calcium oxide (CaO) and carbon dioxide gas (CO_2), the latter escaping to the top of the stack.

Later on, when we reached the very hottest region in the "bosh," where the temperature was about 3,000 degrees Fahr., several other actions simultaneously took place about us. The hot lime here was forced by the converging walls of the bosh into intimate contact with all the other oxide portions of the stock, *viz.*: The silica and ash (SiO_2), the alumina or clay (Al_2O_3) and a portion of the sulphur. When these three substances were brought into contact at this high temperature with the lime, the four formed a pasty mass, which united chemically and fell into the hearth below as a liquid "slag." Any one of the oxides by itself would have required a much higher temperature than 3,000 degrees to melt it. In this mass all of the earthy impurities introduced with me as a part of the charge were collected and reduced to a molten state. Being much lighter than iron, the liquid slag floated on top and was easily drawn off at intervals through a "cinder notch."

[TO BE CONTINUED]

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